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PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL
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IN THIS ISSUE: Collins—*The Cayenne Pineapple* • Schwabe—*Life History of* Oxyspirura mansoni • Akamine—*Viability of Forest Tree Seeds* • Marples—*Pacific Symphytognathid Spiders* • Webster—*Polynesian Species of* Myoporum • Hubbs—Carcharhinus longimanus *in the East-Central Pacific* • Neal—*Flowers of* Cassia fistula • Schwartz and Schwartz—*The Lace-necked Dove in Hawaii* • NOTES

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MAR 1[illegible] 1951

Notes on the Origin, History, and Genetic Nature of the Cayenne Pineapple[1]

J. L. Collins[2]

Although plants and fruits of the pineapple had been carried from America to Europe a number of times following their discovery by Columbus in 1493, it was almost 100 years before they were successfully grown in Europe. They were first grown to fruiting in Holland about 1690 and in England some 30 years later, following the development of artificial heating of glasshouses.

Thereafter, a great rivalry and enthusiasm developed in the growing of pineapples by the gardeners of the large estates in England and on the continent. They imported varieties from America, exchanged varieties among themselves, and in some instances developed new varieties by growing the seeds which were occasionally found in their fruits or were obtained from the West Indies. As a consequence of this general interest in the growing of pineapples, the horticultural journals of the times frequently carried articles or notices concerning the culture of this fruit.

Like a number of important agricultural crops, the Cayenne variety of the pineapple, *Ananas comosus* (L.) Merr., appeared upon the horticultural scene with no definite record of the manner or the place of its origin. The first reference in the literature to the Cayenne variety appears to be the short notice carried in the *Gardeners' Chronicle* (England) of March 6, 1841, under the column heading of "Foreign Correspondence," as follows:

Paris, Feb. 4, 1841. As information is continually demanded by horticulturists regarding pines, perhaps a few words as to the varieties in request in Paris and the mode of culture may not be unacceptable. The Potager, or Royal Kitchen Garden Versailles has the merit of producing this and other fruits in the greatest perfection. . . . The pinery consists of a vast number of pits, succession and fruiting houses, the whole of which are heated with hot water; it contains about 2000 plants among which are fine specimens of Queens, Cayenne Lisse and Espineux, Black Jamaica . . . in all about 40 varieties. Only four kinds are considered desirable for general cultivation; of these, however, more than 1000 plants are annually fruited, namely 700 Queens and 300 Cayennes, Endville, and Providence. The Cayenne, both smooth and prickly, is of an excellent flavor and weight on the average from 9 to 12 pounds.

This article continues to record the names of the three principal growers, or nurserymen, for the French market, one each in Paris, Versailles, and Meridon, who list Cayenne plants along with some other varieties.

From this date, 1841, we trace the history of the Cayenne variety and map its distribution in geography and time.

In this first reference to the Cayenne variety, mention is made of the smooth-leaved and spiny-leaved forms. Genetic studies in Hawaii (Collins, 1936: 467) have shown that the smooth-leaved type infrequently produces spiny leaves; if we can judge from this modern behavior, then we can assume that the original Cayenne variety had smooth-edged leaves and also produced mutations giving rise to the spiny-leaved form as bud sports.

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[1] Published with the approval of the Director as Miscellaneous Paper No. 48 of the Pineapple Research Institute of Hawaii, Honolulu, Hawaii. Manuscript received August 23, 1950.

[2] Department of Genetics, Pineapple Research Institute of Hawaii.

In the *Gardeners' Chronicle* for January 6, 1844, we find another reference to Cayenne in the section on "Notices to Correspondents," as follows: "The Cayenne pine is from French Guiana; cannot state its price, that is the affair of the nurseryman. . . ." A reader of this journal had obviously written to the editor inquiring about the place of origin of Cayenne and the price of plants, and the editor's reply indicates that it had been imported from French Guiana.

In a description of the Cayenne variety in "The Pineapple Manual" (Anonymous, *ca.* 1870), we find the statement that "This fine variety was imported from Cayenne many years ago and is now cultivated in many places."

These scattered and brief references, together with whatever weight may be given because of the name it bears, point rather clearly to Cayenne in French Guiana as the place from which this variety was introduced into France some time before 1840.

The fact that three French nurserymen in 1841 had sufficient material to offer Cayenne plants in their catalogues indicates its presence in France for a number of years previous to that date. In the "Pineapple Manual" mentioned above, the statement is made that "Cayenne is not very free in producing suckers." At the present time we consider that healthy plants will produce an average of about four reproductive shoots each in a 2-year growth period. The rate of increase from a small beginning would be very slow and could well require 15 or more years to produce enough plants so that three nurserymen could offer them for sale. Accordingly we may assume that a few plants may have reached France around 1820 to 1825.

MIGRATIONS OF THE CAYENNE VARIETY

With the distribution of plants to nurserymen in France, Cayenne soon became a favored variety in Europe because of its large, well-shaped fruits, good color, and fine flavor, although the Queen variety was also widely grown and well received. The earlier distribution of Cayenne to other countries appears to have stemmed from England and not directly from France. This early distribution from England is also emphasized by its early appearance in some of the British colonies, it having reached Australia by 1858 and Jamaica in 1870, although it came to Jamaica via Florida. In Australia its development was fairly rapid and from 1890 to 1895 that country was able to furnish many slips and suckers for expanding the pineapple industry in the Hawaiian Islands, although the first Cayennes came to Hawaii from Florida in 1885 and Jamaica in 1886.

The decade from 1885 to 1895 was a period of accumulation of the Cayenne variety in the Hawaiian Islands. Introductions of pineapple plants were made from 11 different tropical countries (Florida, England, Jamaica, Bahamas, Trinidad, Puerto Rico, Mexico, Australia, Singapore, Samoa, and Algeria) four of which were known to have included the Cayenne variety. It is possible that it may have been included in shipments from other countries as well, but the records do not list the varieties in some importations (Collins, 1934: 129).

Figure 1 shows two major centers of distribution of the Cayenne variety to other areas. England played this role during the last half of the nineteenth century, although the first European propagation was accomplished in France. Hawaii has been a major source of distribution during the first half of the twentieth century. It was doubtless sent to still other countries from these three major centers of distribution, but at present we do not have complete records. For instance, it was imported from Ceylon into South Africa, but we do not know how it reached Ceylon.

THE ORIGIN OF CAYENNE

The discussion of the Cayenne variety up to this point is based upon documentary evidence. In trying to trace the origin of the Cayenne pineapple beyond the realm of

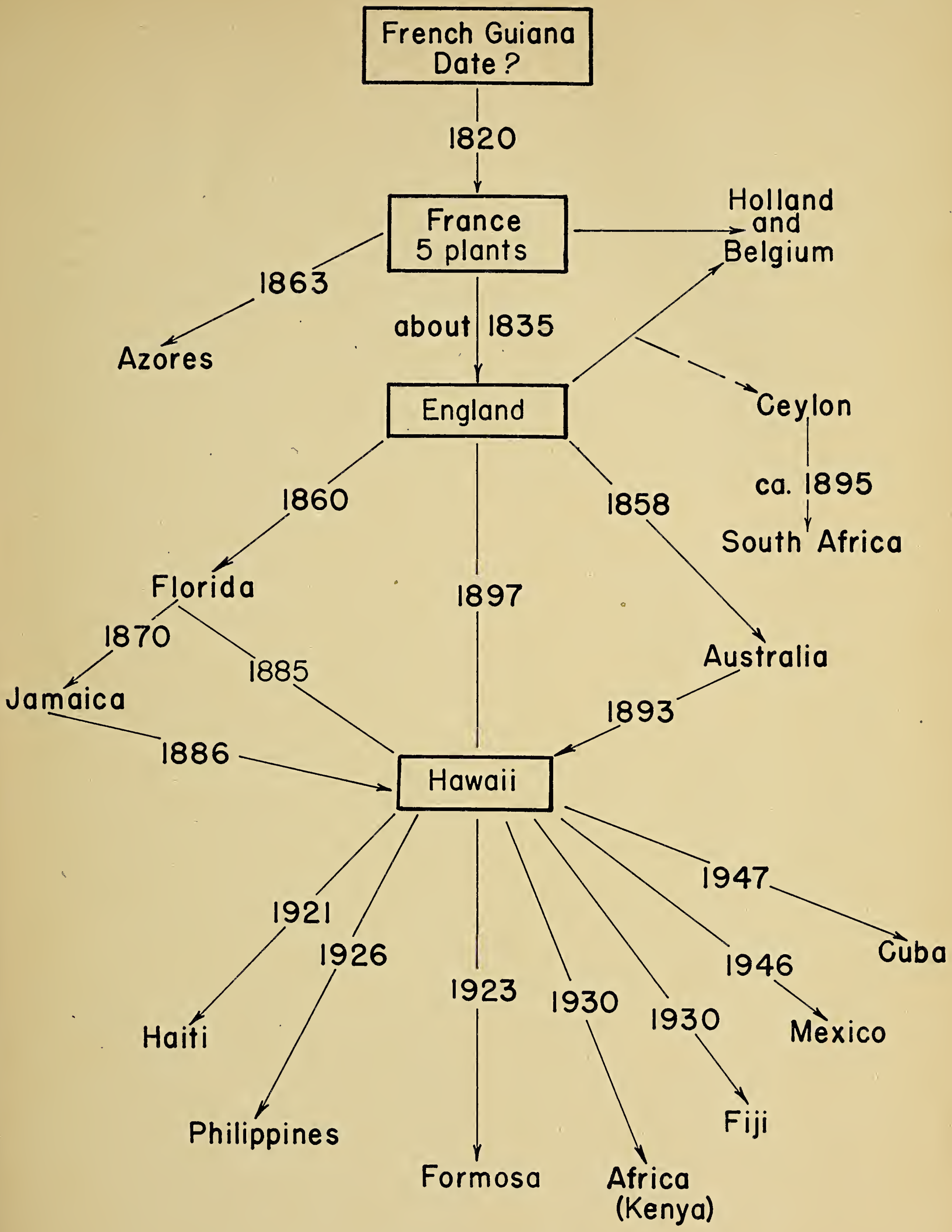


FIG. 1. Distribution of Cayenne following its introduction into France in 1820. Two major centers for distribution appear: first England and then Hawaii.

definitely known or documented history, certain additional conclusions regarding its still earlier history have been based upon circumstantial evidence.

As has already been stated, some of the early horticultural journals in England mentioned that the Cayenne variety had been imported from French Guiana. The name it bears is also circumstantial evidence for that conclusion. This latter statement is based upon the frequency with which plants, particularly the pineapple, are given names according to the place from which the varieties are obtained, even though they already possess local names. Among pineapples there are a number of varieties named after geographical areas in the West Indies and South America. Among these may be mentioned the following:

WEST INDIES	SOUTH AMERICA
Antigua	Bahia
Providence	Esmeralda
Jamaica	Pernambuco
St. Kitts	Taboga
Cuban	Surinam
Havannah	Trinidad
Puerto Rico	Demerara

In the hope that further knowledge regarding the history of the Cayenne variety might be found in French Guiana, a search was made of the botanical literature for reports of plants and plant collections in the northern part of South America. This search disclosed the information that in 1819 the French government sent an expedition to the French colonial possessions in America and the Pacific Ocean area to collect plants and seeds for the French botanical gardens at Paris and Versailles. Samuel Perrottet, the botanist on this expedition, filed a report of the plants collected, in which he records finding a new variety of pineapple growing at Cayenne, in French Guiana, having spineless leaves (the others in the region having spiny leaves) and delicately flavored fruits averaging about 20 pounds in weight (Perrottet, 1825: 103).

He collected and sent to Versailles five plants of this variety in 1820. This date fits in well with that which we have suggested above as being about the time the Cayenne variety is presumed to have been introduced into France.

The description, as it appeared in Perrottet's report, is included here as a part of the history of this variety, with a free translation following it.

Bromelia mai-pouri. Perr. Cette nouvelle espèce d'*ananas* provident de Cayenne; cinq plantes ont été, comme je l'ai dit déposés au jardin des primeurs à Versailles. Le mai-pouri n'a point les feuilles armées de dents comme ses congénères; ses fruits, d'un manger fort délicat, pèsent d'ordinaire 10 kilogrammes (20 livres), et sont très-beaux. M.

This new species of *Ananas* was procured from Cayenne; there were five plants as I have said, deposited in the garden of new varieties at Versailles. The mai-pouri does not have spiny leaves like its relatives; its fruits, of a very delicate flavor, weigh on an average 10 kilograms (20 pounds) and are very fine.

The description given by Perrottet is in itself not sufficient to establish the identity of "*Bromelia mai-pouri*" and the Cayenne variety. In fact, the 20-pound *average* weight of fruit mentioned by Perrottet is difficult to believe of any variety of pineapple and must represent an error in the record. The varieties Trinidad and Cabezona were reported to have fruits sometimes reaching 20 to 24 pounds, but there is no other reference to a variety having an average fruit weight anywhere near 20 pounds.

In commenting upon this description of *Bromelia mai-pouri*, Dr. L. B. Smith, of the National Museum in Washington, D. C., remarked that it looked as if someone made a major error between collection and publication. An inquiry concerning these plants sent to the Natural History Museum in Paris resulted in information that no herbarium specimens now existed of this Mai Pouri variety, but that they were considered the same as Smooth Cayenne in 1850 by Gautier, "the famous grower of Parisian pineapples." The director of the museum stated that the duplication of names had been published, although the term "Mai Pouri" remains an unsupported name.

The supporting evidence of the date of its introduction into France and the postulated date based on the offering of plants for sale by nurserymen in 1841, together with the statement that Gautier believed the two to be identical in 1850, leads us to conclude that the five plants collected by Perrottet in 1820 represent the beginning of the Cayenne variety in France.

How did this variety get started in French Guiana? This question cannot now and perhaps may never be answered with certainty. The collection of five slips sent to France in 1820 we believe to be of the variety now known as Cayenne. Some time after it reached France it was given the name it now bears.

The name used by the French botanist in his report is somewhat confusing, since he calls it a new species of *Ananas*, yet listed it as *Bromelia*, a closely related genus in the pineapple family. However, Perrottet probably used the name given to him at the time he collected it. The name "Mai Pouri," by which this variety may have been known in French Guiana, probably followed the pattern of indicating the place from which it originated when it first appeared in French Guiana. The quest of the origin of the Cayenne was then continued in a search for a geographical area or locality having the name "Mai Pouri."

In Colombia, at the junction of the Triparro River with the Orinoco River, is a small village called "Maipures." In this region, and in the watershed of the Venturari River in Venezuela, also a tributary of the Orinoco, lived the Maipure tribe of Indians. We now believe that the Cayenne pineapple originated in the interior region of Venezuela long occupied by the Maipure tribe of Indians, and that it was probably grown and used by them for a long period of time (Fig. 2). Velez (1946: 427), who recently traveled through the upper Orinoco River basin, states that the Piaroa Indians have had under cultivation since time immemorial several pineapple varieties which yield large, well-flavored fruits.

Another circumstance which may also have a connection with Maipure pineapple concerns the Esmeralda pineapple variety, grown in Mexico. This variety is very similar, if not identical, to the Cayenne variety. Esmeraldas is the name of a small village at the mouth of the Esmeraldas River in northern Ecuador, in South America. The Maipure pineapple could have been carried from Venezuela or Colombia into the Esmeraldas region of Ecuador and thence into Mexico, where it was given the name of the place from which it had most recently come. We have no indication that it was known as Maipure while being grown in Ecuador, but there is good evidence that the Esmeralda and the Cayenne are the same variety.

How long had this variety been grown in the country of the Maipure Indians and why was it not found by Europeans at an earlier date? To the first question there is no definite answer. We suspect that the history of this variety may extend back into the antiquity of American civilizations along with such notable plants as corn, tobacco, and potatoes.

To the second question a logical answer is apparent. That area of South America is even today largely unexplored, partly because it has long been inhabited by Indians who have had little contact with outside people and because of the difficulty of travel in this little-frequented and still primitive area. The Maipure Indians, who at one time roamed over this area, no longer exist as a distinct ethnic group.

Sir Walter Raleigh, who conducted an expedition in 1595 up the Orinoco River for about 200 miles, reported having received quantities of pineapples from the Indians in the deep interior of the country. The village of Maipure on the Orinoco River is at the place now marked on maps as the head of navigation. This is some 200 miles farther up the Orinoco than the place reached by Raleigh. Could Sir Walter Raleigh and his men have been the first white men to find and eat the Cayenne pineapple?

If the Cayenne pineapple originated in the Maipure Indian country, the parent variety or species may still be present as a part of the native vegetation. Other members of the hybrid population of which our Cayenne variety was a member may still be among those used by the Indians. Could some of the sibs of the Cayenne variety be better fitted for large-scale commercial production? Could some of the sibs have inherited resistance to diseases which Cayenne failed to obtain? Could some of the sisters of Cayenne have inherited two or more genes for yellow flesh color, where Cayenne obtained only one?

These are some of the questions which have been raised by this study of the origin of the Cayenne variety of pineapple, to which answers should sometime be obtained.

VARIATIONS WITHIN THE CAYENNE VARIETY

Two types of hereditary variations, which may be designated as strain differences and mutations, exist within the variety.

Strain differences

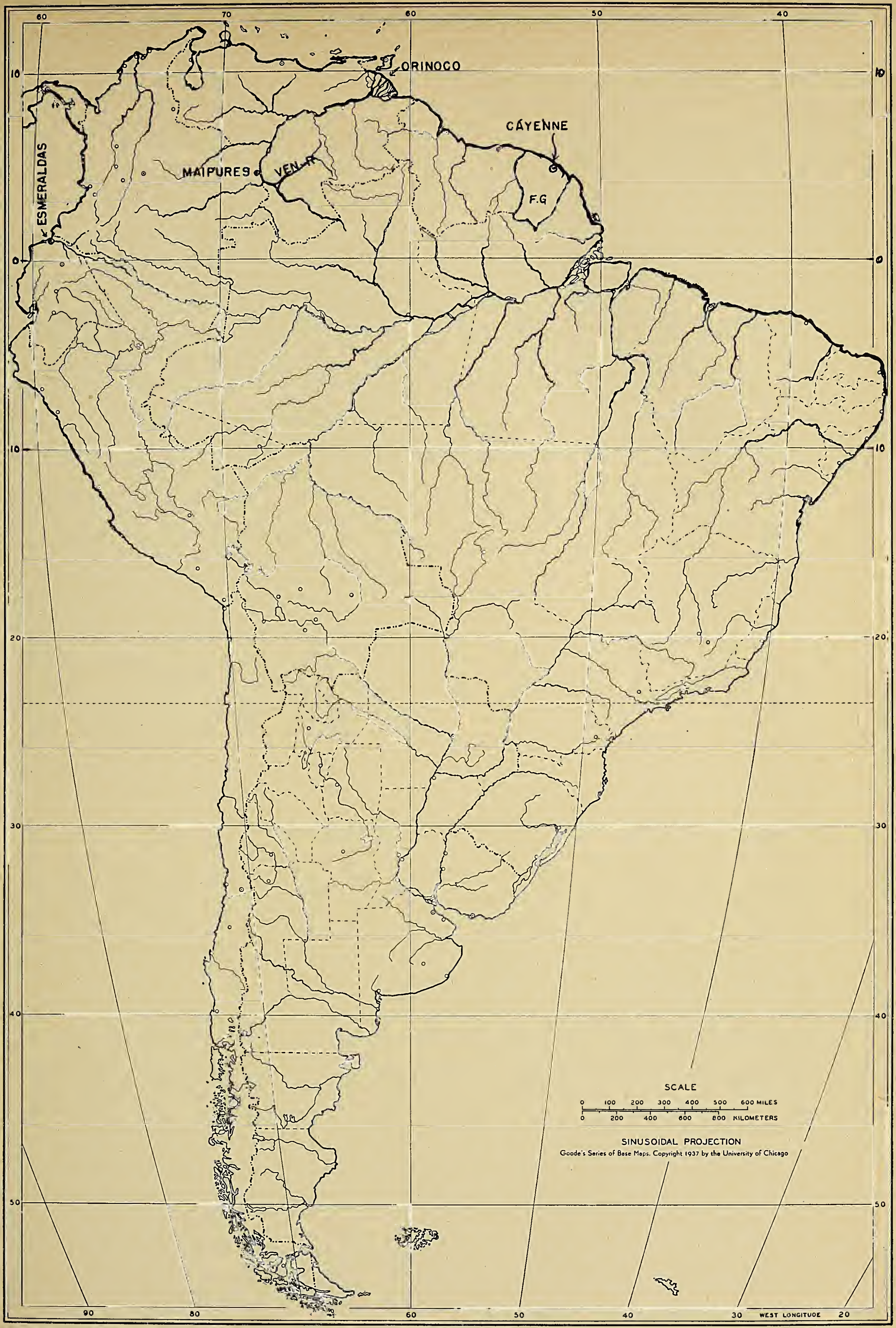
The term "strain" is used here to indicate hereditary differences in fruits or plants within a variety when the manner of origin of these differences is not known. A long time ago growers of this variety recognized strain differences. The *Journal of the Jamaica Agricultural Society* (about 1900) carried a statement that there was a good and a poor kind of Smooth Cayenne and that the latter was also known as the Honolulu kind!

Captain John Kidwell, an early pioneer of the pineapple industry in Hawaii, stated (Kidwell, 1904) that there were two distinct types in Hawaii, and that he considered one much superior to the other. The poor type of Cayenne, according to his statement, had been imported from Queensland, Australia, under the name of Smooth Cayenne. He described it as having a very large plant producing fruits weighing from 7 to 15 pounds and numerous slips on the peduncle beneath the fruit. The fruits, while of good quality, were conical in shape and possessed a very large core. The other type, which he called the "true" Cayenne, was similar in appearance, but the plants were smaller and produced fruits from 5 to 7 pounds in weight. This type did not produce slips on the peduncle beneath the fruit. As a consequence of this latter characteristic, this good strain was necessarily propagated from suckers and the crowns.

In 1887 a report of the United States Department of Agriculture on tropical and subtropical fruits mentions three kinds of Cayenne being grown in the Key West region of Florida. These were listed as Smooth Cayenne, Spine-leaved Cayenne, and Thompson's Smooth Cayenne. No description of the third kind was given, but its listing as a separate strain indicates that it may have been different in some respect from the others.

In Hawaii we recognize three strains of Cayenne, all of which produce good canning fruits but differ in some plant and fruit characters. The one used most extensively throughout the Islands is known simply as Cayenne. The second strain, grown mostly on Kauai, is known as the "Hilo" variety, or as the Hilo Cayenne. The Hilo variety differs from Cayenne in at least three characters. The most prominent difference is in the absence of slips in the Hilo variety. It also produces a smaller plant and fruit, with the fruit more cylindrical and of better average quality. It produces more suckers than Cayenne and the plants have a darker green leaf color. These differences are about the same as those Captain Kidwell used to distinguish between Cayenne and what he called the Queensland type. The strain we now call Hilo appears to

FIG. 2. Location of the probable area of origin of the Cayenne pineapple, showing the location of the town of Maipures on the Orinoco River. The Venturari River (Ven. R.) area, for a long time the country of the Maipure Indians, is also shown.


ORINOCO
CAYENNE
MAIPURES
VEN.-R
F.G
ESMERALDAS
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SINUSOIDAL PROJECTION
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WEST LONGITUDE
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GOODE'S SERIES OF BASE MAPS
HENRY M. LEPPARD, EDITOR

Prepared by Henry M. Leppard
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TABLE 1

Classification of Somatic Mutations in Cayenne

FRUIT MUTATIONS

- I. Foliar proliferation of the fruitlet
  - 1. Crowning Beauty
  - 2. Hour Glass
  - 3. Slipping Beauty
- II. Multiplication of floral organs
  - 4. Flowering Beauty (increase in petal number)
  - 5. Multiple sepals and bracts
- III. Disappearance of floral structures
  - 6. Dry fruit (only the floral bract subtending the fruitlet remains)
  - 7. Bottle Neck (the upper one half to one third of the fruit is like the dry fruit)
- IV. Changes in fruit characters
  - 8. Elongated bracts and sepals
  - 9. Big eyes
  - 10. Slender
  - 11. Elongated fruit
  - 12. Self seedy
  - 13. Rough (pointed eyes)
  - 14. Non-porous flesh
  - 15. White flowers
  - 16. Nubbin (dwarf and abnormal fruit—eyes small and distorted, surface very rough) M226

PLANT MUTATIONS

- V. Single character changes
  - 17. Spiny leaves
  - 18. Absence of anthocyanin
  - 19. Linear anthocyanin
  - 20. Blush anthocyanin
  - 21. Intensified anthocyanin
  - 22. Albino (no chlorophyll)
  - 23. Streaked anthocyanin
  - 24. Waxy (absence of trichomes)
  - 25. Semi-waxy (reduction in trichomes)
  - 26. Mealy (increased trichomes)
  - 27. Few slips (573, M4W)
  - 28. Increased number of slips (L69)
  - 29. Multiple crowns
  - 30. Increased wilt tolerance (resistance)
  - 31. Increased chlorophyll (LH8)
- VI. Multiple character changes
  - 32. Paper Leaf (degenerate plant)
  - 33. B.B. (gigas form)
  - 34. Lanai (short leaf type)
  - 35. Driver's Dwarf (dwarf)

be identical with the one Kidwell called the "true" Cayenne.

Our third strain is known as the Collar-of-Slips, because of the excessive number of slips produced around the base of the fruit. It has a smaller fruit than the Hilo, is later in maturing its plant and ratoon crops, and is generally considered an undesirable type.

These Cayenne strains have been present as components of the variety for a long, long time. How they originated or which represents the true or original Cayenne cannot now be determined with certainty.

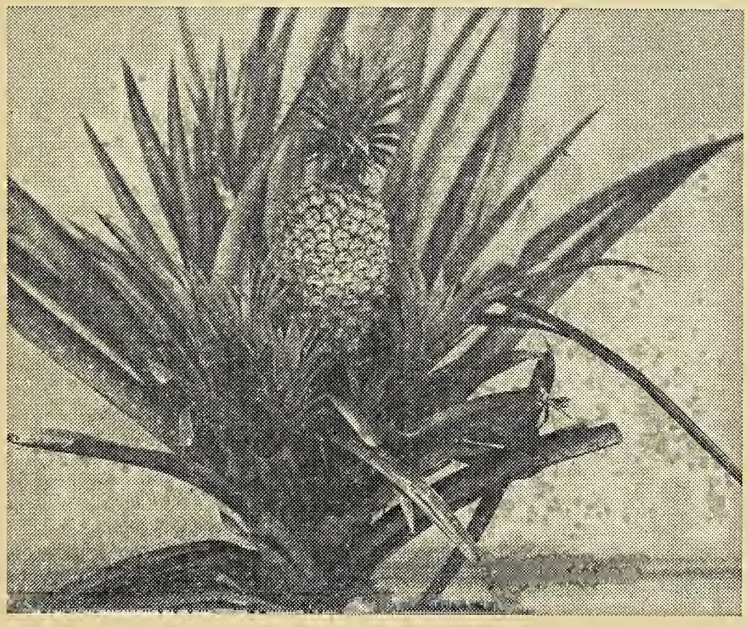

Fig. 3. A plant of the Cayenne variety, showing slips, suckers, and a mature fruit.

Figure 3 shows a typical Cayenne plant with slips, suckers, and a mature fruit.

Mutations

The term "mutation" is applied to new hereditary variations which appear *de novo* in a population of plants or animals, caused by a change in the structure of a chromosome and thus in the hereditary constitution of the individual.

Mutations have occurred in the Cayenne variety, giving rise to a series of new or changed forms; some are so profoundly changed that they no longer show the variety characters, others show only minute changes.

These mutant forms are treated separately from the strains already discussed, principally because we know something about the origin of these mutations and we do not know how the strains originated. It is quite possible that the latter also started as somatic mutations.

The mutations in Cayenne can be conveniently divided into six classes on the basis of the characters which are altered. Four classes affect the fruit and two classes affect both fruit and plant characters (Table 1).

The mutations listed in the first five classes of Table 1 are relatively slight or small character alterations. They influence one or a few characters and do not, for the most part, represent profound genetic changes, even though the character alteration may be conspicuous. The mutant Crowning Beauty (Fig. 4) is an example of this kind of mutation.

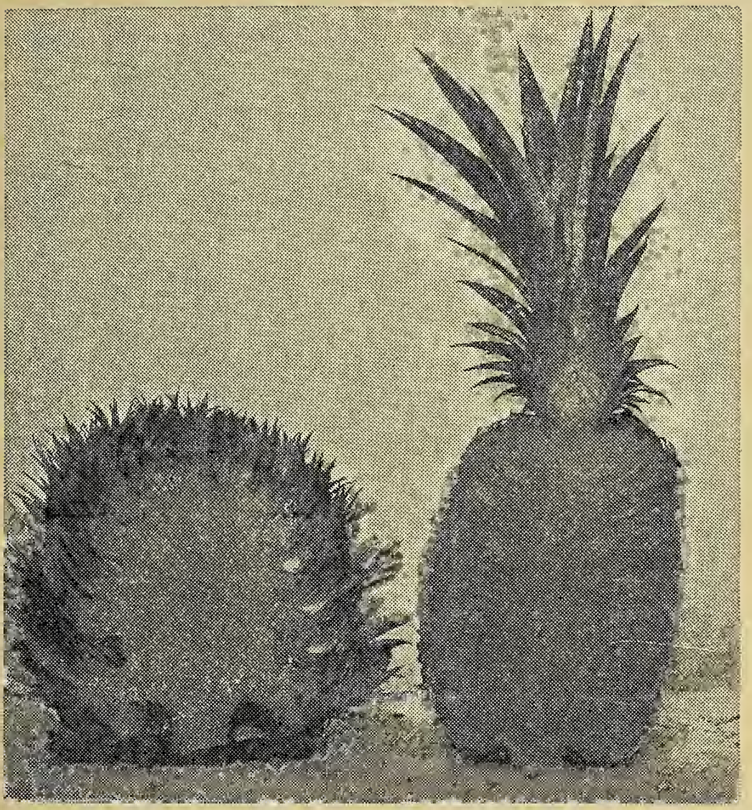

FIG. 4. A normal Cayenne fruit cut in longitudinal section on the right, showing internal structures of core, carpels, and vascular fibers. On the left is the mutant type Crowning Beauty, showing foliar proliferation of the fruitlets and absence of normal carpel structures.

Those in Class VI, however, stand apart from the rest because they represent simultaneous changes in a number of different morphological and physiological characters.

The Lanai type and B.B. mutations (Fig. 5) appear to be complementary to each other in their deviation from the normal variety. They vary from typical Cayenne in opposite directions in at least six characters, shown in Table 2.

TABLE 2
CHARACTERS OF MUTANTS B.B. AND LANAI COMPARED WITH THOSE OF THE NORMAL VARIETY

CHARACTER	VARIATION FROM TYPICAL CAYENNE	
	In B.B.	In Lanai
Leaf number	decreased	increased
Leaf length	increased	decreased
Fruit size	larger	smaller
Fruit maturity	later	same as normal
Plant size	larger	smaller
Spines	more	normal

The Paper Leaf mutant departs so widely from the normal variety in a number of characters that it no longer resembles the Cay-

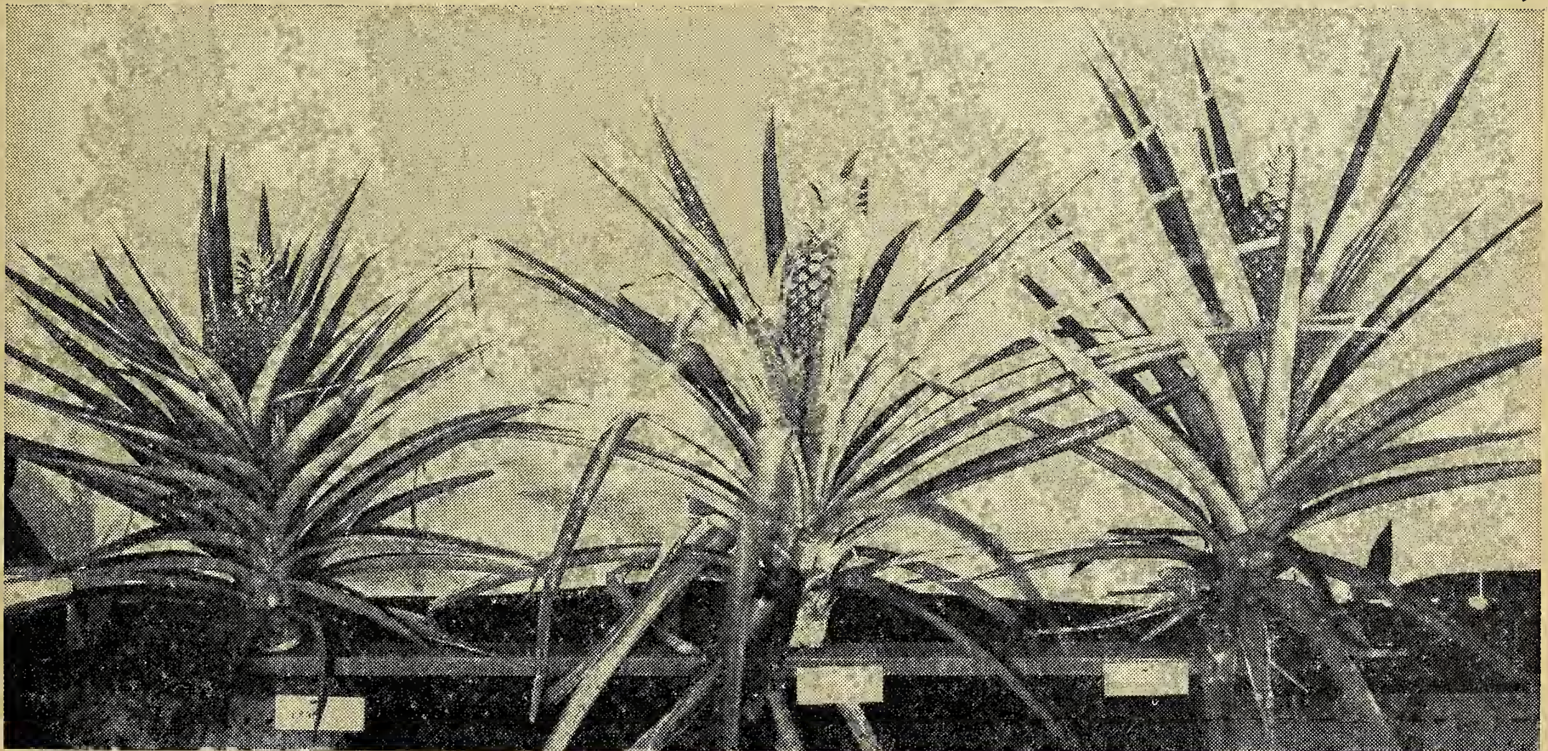

FIG. 5. A normal Cayenne plant in the center, with the short leaf Lanai mutation on the left and the long leaf one on the right. These represent changes in opposite directions from the normal.

enne at all. It is considered a degenerate type, because of its small, worthless fruit and weakly growing plant. It probably could not survive in field competition with normal plants.

Driver's Dwarf (Fig. 6) has a diminutive form of plant and fruit, combined with collar of slips and an intensified purple anthocyanin pigment in the leaves. This may represent a change from the normal slip type of the Cayenne variety to the collar-of-slip strain. On the other hand, the mutation giving rise to dwarf and increased anthocyanin may have occurred in a collar-of-slip strain plant which was already in the field population. The dwarfing and anthocyanin intensification appear to have been simultaneous changes.

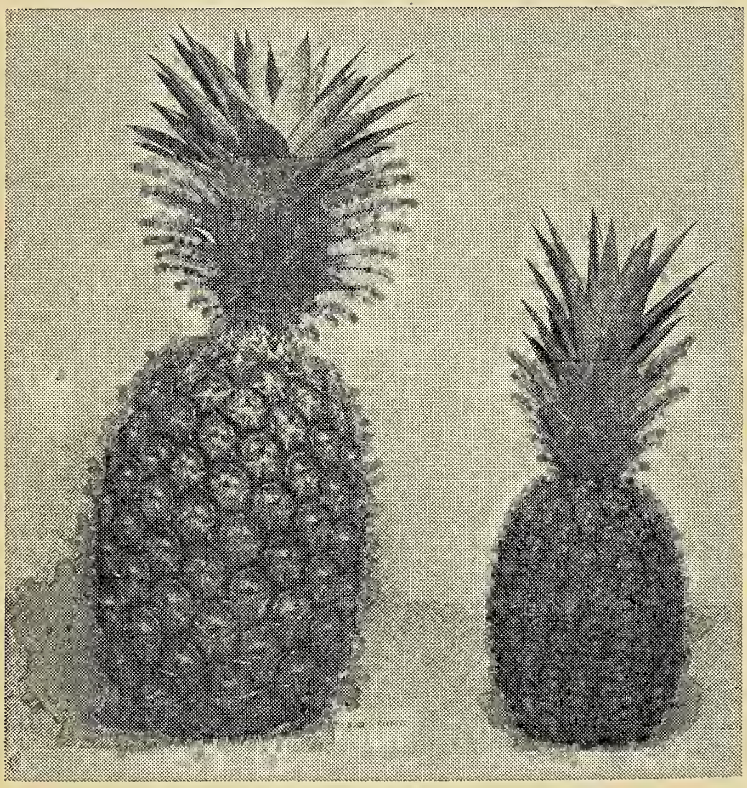

FIG. 6. A normal Cayenne fruit on the left, with a fruit of the mutant Driver's Dwarf on the right.

Discussion of these more obvious mutant types naturally leads to the question of the possible occurrence of other mutations which are less conspicuous and less easily measured. Undoubtedly mutations of this kind take place, but the demonstration of the existence of mutations of slight phenotypic effect is much more difficult, because of overlapping variations of a non-hereditary nature.

Some examples of these small or elusive mutant effects are briefly described to show that at least a few are present in the variety.

Two Cayenne clones were found to show a slightly darker green color, which could be recognized easily when a fairly large group of these were growing adjacent to a group of the normal variety. A clone may be thought of as one plant multiplied many times by vegetative reproduction, and all plants of a clone have identical heredity. Chemical analyses of leaves revealed a higher chlorophyll content in these darker green leaves. A mutation of slight effect on chlorophyll production was probably the origin of these darker green clones.

The elongated fruit mutation listed in Table 1 develops a large number of multiple crowns and fasciated fruits when grown in warm, dry areas, but only normal plants appear in the cool, more moist areas. In this case the additional character of multiple crowns is quite obvious under one environmental condition and disappears (or merges into the normal pattern) when grown under other conditions.

The number of slips produced per plant is a character subject to considerable variation due to differences in the environment during the growth period. This is well illustrated by the effect of relative crowding of plants in the field. Close planting reduces the number of slips, and, conversely, widely spaced plants permit a larger number of slips to develop. Table 3 shows the variation in number of slips resulting from an experimental planting of Cayenne with 10, 12, 14, and 16 inches between plants (that is, with different degrees of crowding).

TABLE 3

EFFECT OF DIFFERENT PLANT SPACINGS ON SLIP PRODUCTION

PLANT SPACING IN INCHES	AVERAGE NUMBER OF SLIPS
10	2.51
12	3.33
14	3.95
16	4.36
Odds — 19 to 1	0.43
Odds — 99 to 1	0.60

Because of the susceptibility of this character to variation due to environmental dif-

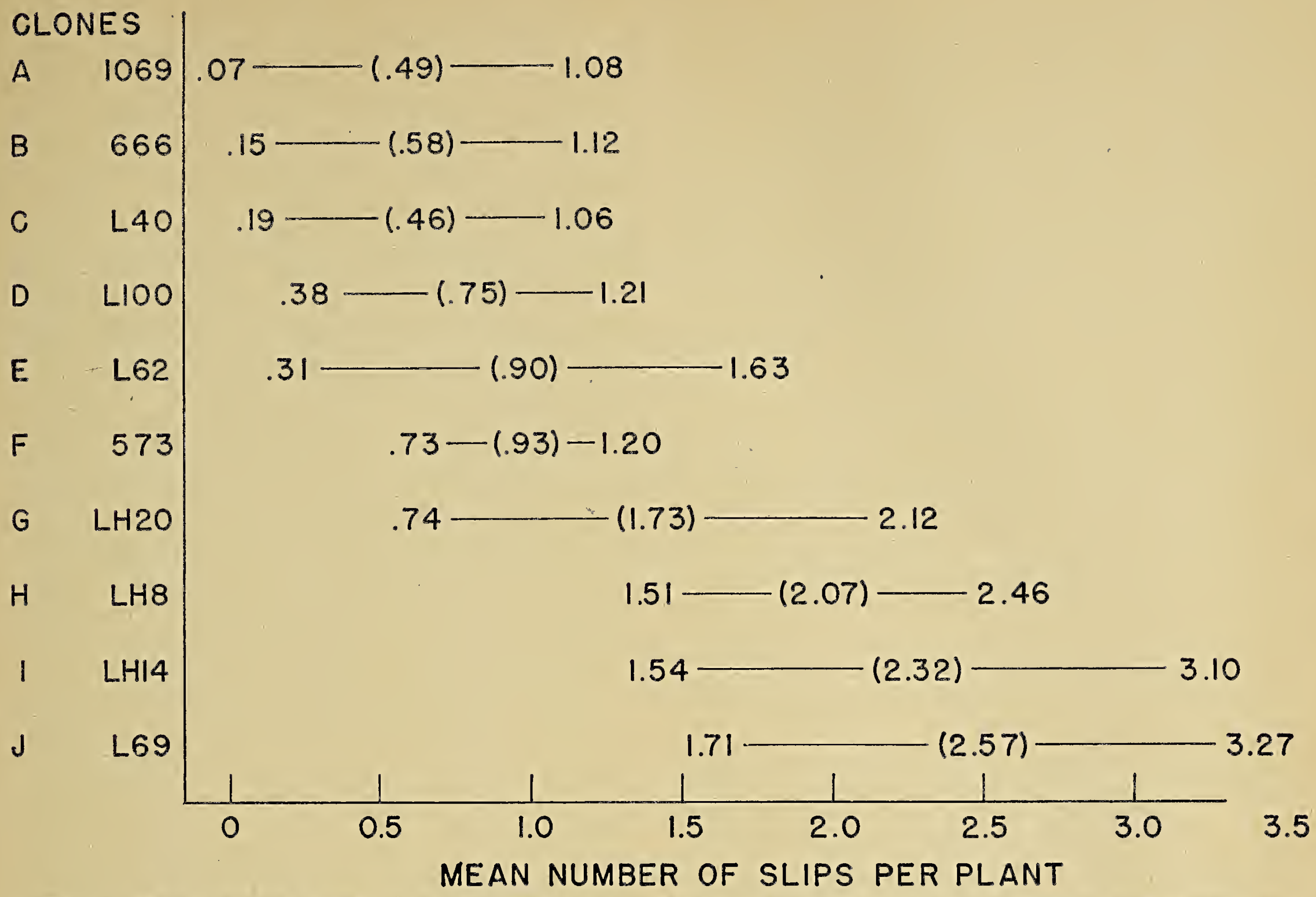

FIG. 7. Ten Cayenne clones showing mean slip numbers for a period of 7 years, together with lowest and highest yearly means.

ferences, the discovery of genetic variations (somatic mutations) which have an effect on slip number is more difficult than locating mutations which are not subject to environmental modification. However, by repeated tests under similar environmental conditions it has been possible to demonstrate the occurrence of mutations affecting number of slips in this variety.

Figure 7 shows the mean number of slips per plant for 10 clones over a period of seven plant crop harvests, together with lowest and highest limits of the yearly means for that period. Five of the clones had a range of annual mean slip number which did not overlap the range of three other clones. Two clones, E and G, had a range of variation which overlapped all the other groups. There can be little doubt about a genetic difference existing between any one of the three high slip-producing clones, H, I, J, and any one of the five low-producing clones, A, B, C, D, and F.

The three high slip-producers, H, I, and J, do not appear[3] to differ among themselves. Clone G, overlapping in its range with both the high and low slip producers, appears to be genetically different from both groups.

These mutant clones can be compared with each other, but should not be compared with the mean of the variety, first because they are a part of the variety and second because—the variety being a mixture of genetic types—random samples would not always include the same distribution of variant types. Furthermore, most Cayenne populations include some plants of the collar-of-slip strain, which produces a very high number of slips.

The somatic mutations in Cayenne include a range of types varying from those having marked, easily recognized characters to those differing so slightly that only statistical analyses of quantitative data will identify them.

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[3] These conclusions are based upon another replicated plot test which showed significant differences as listed here, and we presume that the causes of the differences were genetic.

They are not frequent in occurrence, with the exception of a few which have been shown to be frequently mutating types (Collins, 1936). The mutations discussed here have been collected over a period of 20 years or more and from among millions of normal plants.

This variety is as stable genetically as are vegetatively propagated, highly heterozygous diploid varieties in general. Were this not true, the variety could not have been maintained through this long period of time.

Cayenne is not the single clone it probably was at the beginning. Now it is a collection of clones, all having the same general characters but usually differing in one or a few characters or degrees of expression of characters. The more obvious mutations and those too poorly adapted to survive in the general population have been and are being reduced to small percentages or eliminated. The remaining population heterozygosity consists of minor character alterations which are carried along by asexual propagation in the general mass of cultivated plants. As examples of these latter clonal types, reference can be made to some of those listed in Table 1, such as the clone with less porous fruits, self-seedy types, low and high slip-producing forms, and increased amount of chlorophyll.

As to their value to the organism (in a cultivated variety, positive value in horticulture) these somatic mutations follow the known pattern of randomly occurring mutations; the great majority are either detrimental or of no advantage to the organism. Only three of those which have been studied appear to have possible advantage in pineapple culture, and only two of these, the wilt-resistant mutant and the high slip-producing type, are of possible importance.

TETRAPLOID CAYENNE

The pineapple normally has 50 chromosomes in its somatic cells. This is considered to be the diploid number for the genus *Ananas*. However, tetraploid Cayenne plants having 100 chromosomes were obtained after treating shoot growing points with colchicine solution (Kerns and Collins, 1947). The immediate results from these treatments were various kinds of chimeras of diploid and tetraploid tissues, together with plants which either died early in growth or reverted to normal diploid tissue throughout.

By careful selection of buds from the tetraploid sectors of chimeras during several successive vegetative generations, constant new types which fall into the following three classes on the basis of the amount and location of tetraploid tissue were obtained.

Class 1 was completely tetraploid.

Class 2 was tetraploid except for a diploid epidermis.

Class 3 was diploid except for a tetraploid epidermis.

Classes 1 and 2 were alike in all visible characters. Class 3 was like the normal diploid in all visible characters.

The tetraploid has been compared in Table 4 with the diploid in a number of important characters. The fruit weight is less in the tetraploid and the fruit has fewer eyes than in the diploid. The average eye weight, however, is higher in the tetraploid, showing that the individual eyes of the tetraploid are larger. The Brix (dissolved solids including sugars) of the tetraploid fruit is lower than in the diploid fruit. The characters of fruit acidity, translucence, and vitamin C content are highly variable, so that no significant differences were obtained. These characters are readily altered by different environmental conditions.

Tetraploid plants are taller than diploids, but they have fewer leaves and produce fewer slips. They do not differ in average leaf length, although the tetraploids have wider leaves. The tetraploids also have a higher percentage of water in the leaves and, as a consequence, a lower percentage of dry matter per unit weight of green leaf tissue.

The fruits are seedless, as are the diploids. The chromosomes perform regularly in germ-cell formation, and functional gametes are produced.

Crosses between the Cayenne tetraploid and varietal hybrid tetraploids produce viable seed readily, but crossing with diploid forms produces very little seed; this is similar to the results obtained when varietal hybrid tetraploids are crossed with diploids.

TABLE 4

COMPARISON OF THE FRUIT AND PLANT CHARACTERS IN THE DIPLOID AND TETRAPLOID CAYENNE

CHARACTERS	DIPLOID	TETRAPLOID
Fruit weight (lbs.)	5.8	4.0*
Eye number	140.4	105.6*
Eye weight (gm.)	16.3	16.8*
Brix	15.4	13.8*
Acidity (per cent)	0.71	0.86
Vitamin C	19.2	20.8
Translucence	2.7	2.3
Plant height (cm.)	28.1	30.5*
Number of active leaves	57.6	44.2*
Leaf length (cm.)	65.0	65.2
Leaf width (cm.)	5.4	6.2*
Percentage water in leaves	81.8	83.5*
Percentage dry matter in leaves	18.2	16.5*
Pollen grain diameter (microns)	47.0	64.0*
Stomata size (microns)	22.0	31.0*

*Significant differences.

In many plants, and particularly in ornamentals, valuable horticultural characters are obtained by doubling of the chromosomes (Emsweller, 1948: 570). However, the tetraploid Cayenne is inferior to the diploid form in several important characters (Table 4).

GENETIC NATURE OF CAYENNE

The Cayenne pineapple normally has seedless fruits, although it does produce normal germ cells. The seedlessness results from a condition known as self-incompatibility. Under these conditions the germ, or sex, cells of the same individual do not unite in fertilization to form embryos. Germ cells from two different varieties, Cayenne and Queen, for instance, are mutually compatible and seeds are produced following cross pollination between the varieties.

Inasmuch as inbreeding is thus denied because of self-incompatibility, the studies of the genetic nature of Cayenne have been conducted largely from the results of varietal crossings and from examination of the somatic mutations which have appeared in field populations.

Cayenne has a diploid number of 50 chromosomes; in the somatic cells they appear slightly elongated or almond-shaped (Collins and Kerns, 1931: 140); in the germ cells, they are almost round. While the process of germ-cell production is usually normal, some abnormalities occur. The most frequent abnormality is the formations of germ cells containing 50 chromosomes, which is double the ordinary number of chromosomes in gametes. These appear in the mature sex cells as giant pollen grains and ovules.

In crosses between Cayenne and other varieties, these giant germ cells give rise to occasional hybrids having 75 or 100 chromosomes instead of the normal number of 50 for this species.

The number of these plants whose cells have 75 and 100 chromosomes is far below the expected number on the basis of the percentage of 50-chromosome germ cells produced. This shows that only a small proportion of the plant gametes function in fertilization and that selective fertilization in favor of the normal 25-chromosome gametes takes place.

Hybrid populations resulting from crossing Cayenne with other varieties provide some information regarding the genotype or hereditary constitution of the Cayenne variety.

The variety is heterozygous for many recessive and dominant genes. Table 5 gives some information on the genotype of Cayenne obtained from crossing with other varieties.

INBREEDING IN CAYENNE

In discussing the somatic mutations which have appeared, mention was made of the self-

TABLE 5

THE GENOTYPE OF CAYENNE WITH RESPECT TO CERTAIN CHARACTERS

CAYENNE CHARACTER	CONTRASTING CHARACTER	CAYENNE GENOTYPE	CAYENNE DOMINANCE RELATION
Spiny tip leaves	spiny leaves	Ss	dominant
Spiny tip leaves	piping leaves	pp	recessive
Anthocyanin in leaves	no anthocyanin	Aa	intermediate
Yellow flesh	white flesh	Yy	intermediate
Purple petals	white petals	WW	dominant
Chlorophyll	no chlorophyll	Cc	dominant
Normal fruit	proliferation	*	recessive
Seedless	seedy	*	recessive
Long leaves	short leaves	*	dominant

*Undetermined.

fertile mutation. In this form, the self-incompatibility characteristic of Cayenne is replaced by self-fertility as a result of a dominant mutation, but in all other respects the variety characters remain unchanged.

Inbreeding can now be carried out in the variety by using these self-fertile mutants. Inbreeding is a potent tool for dragging recessive skeletons out of hereditary closets and displaying them in the light of day for all to see. By the use of this tool we have pried out of Cayenne recessive secrets which it has long carried buried within its genotype.

About one fourth of the inbred progeny are semi-lethal and die in an early seedling stage. Another fourth are so weak that they grow very slowly and reach fruiting maturity long after the parent Cayenne. Most of the inbreds are low in vigor, with only a few approaching that of the Cayenne variety. They exhibit a wide variation in fruit and plant types, including many fruit and crown fasciations. The inbred population supplies evidence that Cayenne is not only heterozygous for many recessive and some dominant characters, but that it exhibits heterosis or hybrid vigor.

A number of variations which had appeared in the variety as somatic mutations also appear in the inbred population in numbers indicating Mendelian segregation in a heterozygous genotype.

The general characteristics of the inbred populations supply some evidence regarding the parentage of Cayenne itself. The origin of this variety as a hybrid between any of the known species of *Ananas* can be ruled out, we believe. The parent or parents producing this variety through sexual reproduction must be considered at present as unknown varieties of *A. comosus*, or of such a variety of *A. comosus* and a species of pineapple not known at the present time.

SUMMARY

The Cayenne variety of pineapple was first mentioned in an English horticultural journal in 1841. Evidence is presented to show that it came from French Guiana in 1820. It is presumed to have been grown by the Maipure Indians in the upper Orinoco River valley long before it reached French Guiana. The manner and time of its origin are obscure.

After its introduction into France and England, it became established in many tropical countries during the 100 years between 1840 and 1940.

The genotype of the variety is highly heterozygous and it exhibits hybrid vigor in its growth. The variety is self-incompatible and must be propagated vegetatively. During its long period of vegetative propagation a number of somatic mutations have appeared, including one giving the mutant type self-compatibility. The present Cayenne is a miscellaneous collection of clones. The diploid chromosome number is 50, with 100-chro-

mosome tetraploids obtained by treatment of diploids with colchicine. The tetraploids are inferior to the diploids.

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Studies on *Oxyspirura mansoni*, the Tropical Eyeworm of Poultry. II. Life History

Calvin W. Schwabe[1]

This paper, the second in a series, presents the results of a study made in Hawaii of the life history of *Oxyspirura mansoni*, the tropical eyeworm of poultry. This nematode has been shown by previous investigators to possess a digenetic life cycle in which it utilizes as the definitive host many species of domestic and wild birds and, as the secondary host, a single species of burrowing cockroach, *Pycnoscelus surinamensis*.

The parasite is widely distributed in the warmer parts of the world. It has been reported from Brazil (de Magalhaes, 1888; Almeida, 1933), China (Cobbold, 1880), Indo-China (Fielding, 1928*b*), Mauritius (Emmerez and Megnin, 1901), Reunion (Ozoux, 1910), British West Indies (Hutson, 1943), Formosa (Kobayashi, 1927), British and Dutch East Indies (Picard, 1929; Fielding, 1928*b*), Florida and Jamaica (Ransom, 1904), Hawaii (Wilcox and McClelland, 1913), Guam (Fielding, 1928*b*), and Samoa (Alicata, personal communication). Its near relative (or synonym), *Oxyspirura parvovum*, has been reported from Australia by Dodd (1909).

Apparently Manson's eyeworm has approximately the same circumtropical distribution as its intermediate host (reviewed in Schwabe, 1949). Neither parasite nor host is known to exist in Hawaii at altitudes exceeding 3,000 feet.

The eyeworm is considered important economically in many tropical and subtropical areas. The roach is objectionable not only in that it serves as the vector for the eyeworm, but also because it reportedly damages both roots and bark of certain ornamental and crop plants (reviewed by Schwabe, 1949). Previous to this study the development of the larval and adult stages of this parasite was not well known.

MATERIALS AND METHODS

Surinam roaches in all stages of development were easily collected from soil beneath chicken houses and in chicken yards. Because the incidence of natural infection with the parasite among such roaches approached 100 per cent, only laboratory-raised nymphs were employed in the experimental infections.

Adult *Pycnoscelus surinamensis* females were housed individually in 4-inch glass stacking dishes. A 3-inch disk of filter paper was placed in each dish to provide a hiding place for the roaches during the daytime. Nymphs, isolated at birth, were housed together in the same manner as the adults. The roaches thrived on a diet of whole-wheat bread and water.

Embryonated eggs for infecting laboratory-raised roaches were obtained by macerating gravid female worms. This procedure proved more satisfactory than the involved method of concentration and separation of embryonated eggs from the feces of infected birds.

The gravid worms were taken from the eyes of infected chickens obtained from poultry farms in Manoa Valley and Waialae, Honolulu. The parasites were removed from the eyes of the birds by holding the head rigid and inserting the tips of a pair of dull-pointed forceps beneath the nictitating membrane. Worms thus obtained usually survived for at least 24 hours in physiological saline at room temperature.

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Young nymphs to be infected were first isolated without food or water in clean stacking dishes for at least 48 hours. Nymphs which were dead or enfeebled after this treatment were removed. Gravid female eyeworms were macerated in a drop of water to free the eggs from the vagina and uteri. The entire mass was then soaked up with a small bread crumb. The starved nymphs rapidly ate the moistened bread. It was later found that the nymphs would just as readily consume living female worms so this method of infection was adopted.

A roach to be examined was pinned, dorsal side downward, on a paraffin block. The head was severed with a sharp scalpel and the posterior abdominal segment was teased from the remainder of the abdomen with fine dissecting needles. The rectum remained attached to this segment and the entire alimentary tract was withdrawn in this manner. The alimentary tract and the remainder of the roach were each placed in a few drops of physiological saline solution on separate clean glass slides. Free third-stage larvae, if present, could, with the unaided eye, then be seen wandering about on the slide. Encysted second- and third-stage larvae were readily observed entangled in the Malpighian tubules or attached elsewhere along the alimentary canal, particularly in the region of the rectum.

To observe the late first-stage larvae, the abdominal fat was dissected away from the body wall, placed in a drop of physiological saline solution, and examined beneath a cover slip with the aid of a compound microscope.

In examinations for early first-stage larvae, the crop and esophagus were severed from the remainder of the alimentary canal, teased apart, and examined as a wet mount with a compound microscope. This procedure was repeated on separate slides for the midgut and hindgut.

First-stage larvae were examined as live wet mounts or were stained vitally with methylene blue or fixed in Bouin's solution. Second- and third-stage larvae were examined alive by compressing the cyst beneath a cover slip or by freeing the larvae from the cysts and fixing them in Bouin's solution. Fourth-stage larvae were killed in Bouin's solution and examined as wet mounts.

When living larvae were too active for study they were anesthetized by a crystal of chloral hydrate introduced beneath the cover slip.

The chickens used in these experiments were all hybrid stock (Rhode Island Red × New Hampshire Red) obtained at the age of 2 weeks from the Department of Poultry Husbandry, University of Hawaii. They were housed on wire and fed commercial growing mash.

Third-stage larvae were first obtained in the laboratory by the dissection of large numbers of infected roaches. Inasmuch as this consumed so much time and the larvae were not obtained in the numbers desired, a more satisfactory method was devised. It was observed that when infected roaches were torn apart and placed in physiological saline solution, heated to approximately 37° C., the larvae immediately began to migrate from the tissues of the roaches and to settle to the bottom of the container. This behavior of the larvae suggested the use of the Baermann apparatus, with which an ample supply of infective larvae was readily obtained.

THE ADULT EYEWORM

The sexually mature worms are found beneath the nictitating membranes and in the conjunctival sacs and naso-lacrimal ducts of domestic chickens, ducks, and a number of other wild and domesticated birds.

Anatomy of the adult eyeworm

The adult *Oxyspirura mansoni* is a slender,

TABLE 1

REPORTED MEASUREMENTS OF ADULT FEMALE EYEWORMS

MEASUREMENT	SCHWABE (Oahu, T.H.) 1948–49	RANSOM (Florida) 1904	MAGALHAES (Brazil) 1888	SWEET (Australia) 1910*	FIELDING (Australia) 1928*
Length†	15–17	12–18	16.2‡	13.5–20	15.5–17
Width (ant. end)	69.1–75	50			
Width (max.)	369–538	400–430		270–390	270–420
Width (at anus)	92‡	90–100			
Esophagus length†	1.55‡	1.5			
Esophagus width (post. end)	107‡	80–100			
Intestine width (at esophagus)	61.5‡				
Intestine width (max.)	77–100	100			
Anus to post. end	446–477	400–530	400–530	390–440	364–509
Protostom length	15.4–22	15–25			
Protostom width	35.7‡	25–30			
Mesostom length	22–31	25–30			
Mesostom width	17.3‡	20–25			
Excretory pore from ant. end	410‡	350–400			
Nerve ring from ant. end	232‡	250		220–300	270–320
Vulva diameter	46–61	40–50			
Vulva to post. end†	1.23–1.31	1–1.4	1–1.33	0.78–1.07	0.91–1.55
Vagina length†	2				
Vagina width (near uteri)	57.1‡	50			
Vagina width (near vulva)	36‡				
Uteri width	123–146	100			
Ovary width	22–30				

**Oxyspirura parvovum.*

†These measurements in millimeters; all others in microns.

‡Average measurements (10 specimens).

TABLE 2

REPORTED MEASUREMENTS OF ADULT MALE EYEWORMS

MEASUREMENTS	SCHWABE (Oahu, T.H.) 1948–49*	RANSOM (Florida) 1904	SWEET (Australia) 1910†	FIELDING (Australia) 1928†
Length‡	9.2–13	12–14	9.2–14.5	8.2–15.47
Width (ant. end)	75	50		74
Width (max.)	339	200–350	260–330	254–327
Width (at cloaca)	143	65–150		136
Esophagus length‡	1.37			
Esophagus width (post. end)	107			
Intestine width (max.)	111			
Buccal capsule length	53.5			
Excretory pore from ant. end	410			
Nerve ring from ant. end	285			
Cloaca to post. end	285	320–400		253–390
Long spicule length‡	4.15			3.64–4.55
Short spicule length	232			214–235

*Average measurements (10 specimens).

†*Oxyspirura parvovum.*

‡These measurements in millimeters; all others in microns.

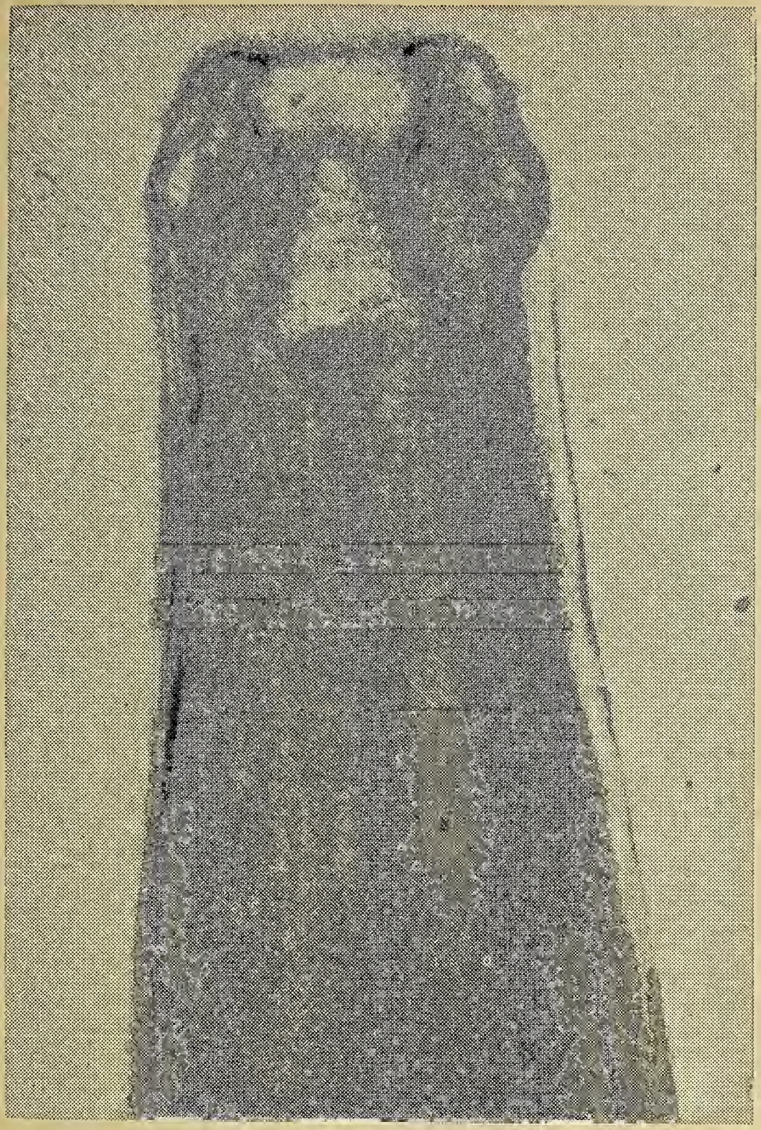

FIG. 1. Photomicrograph showing the anterior end of an adult *Oxyspirura mansoni.*

white, thread-like worm attenuated at both the anterior and posterior ends. Adults studied in the laboratory measured from 9 to 17 mm. in length (Tables 1 and 2). The posterior end is more slender and in the male is curved ventrad. The thin, transparent, outer cuticle is smooth; neither transverse nor longitudinal striations were discernible on worms studied. Magalhaes (1888) reported fine transverse striations; these were not apparent to Emmerez and Megnin (1901) or to Ransom (1904).

The following papillae are common to both sexes: a small cervical papilla with a short hair-like process located on each side of the body approximately 440μ from the anterior end; a pair of small latero-caudal papillae near the posterior extremity of the tail; six minute oral papillae; and four large sublateral cephalic amphids. In the male, six pairs of papillae surround the cloacal opening, four pairs preanal and two pairs postanal.

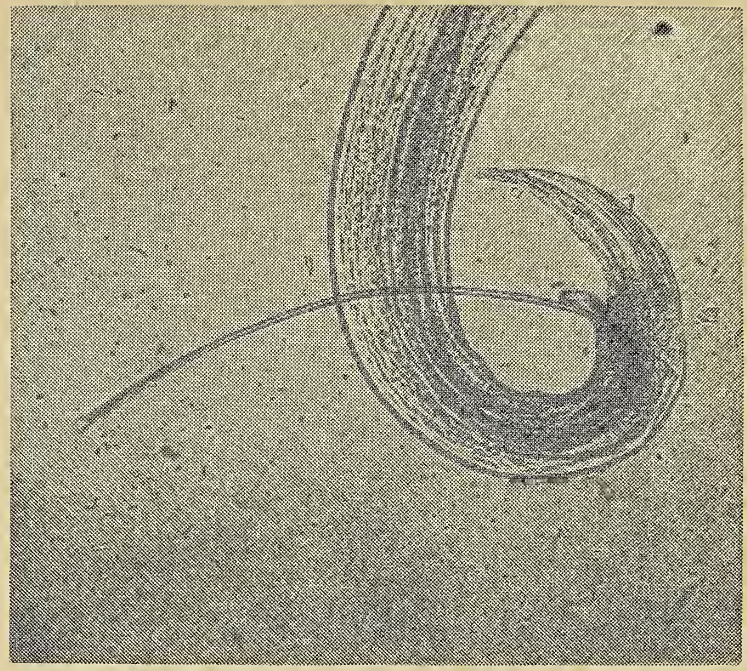

FIG. 2. Photomicrograph showing the posterior end of an adult male *Oxyspirura mansoni.*

The muscle arrangement is of the polymyarian type, with a fan-like arrangement of muscle fibers in the anal region of both the male and the female, attaching the rectum to the dorsal wall.

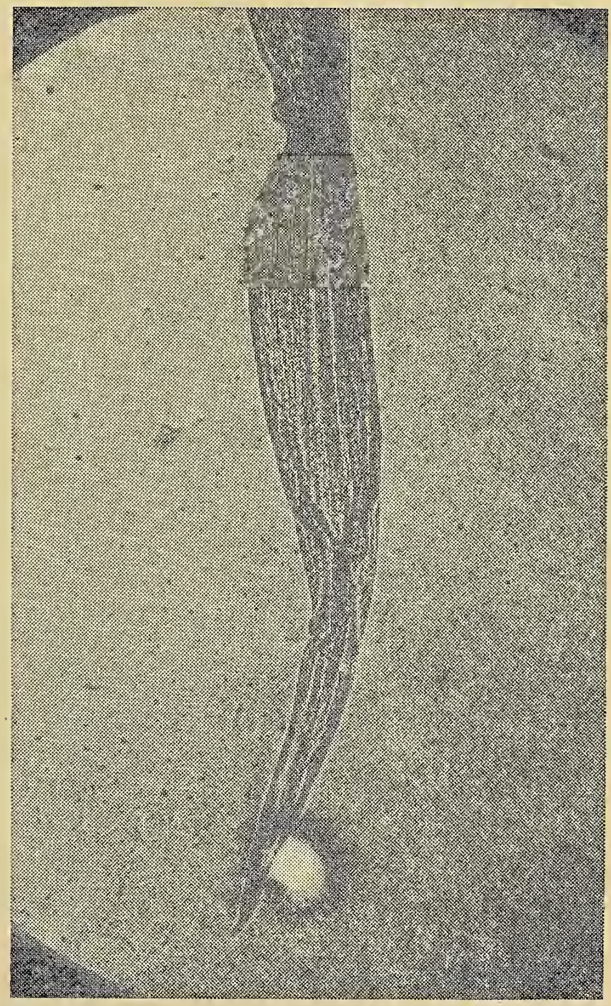

FIG. 3. Photomicrograph showing the posterior end of an adult female *Oxyspirura mansoni.*

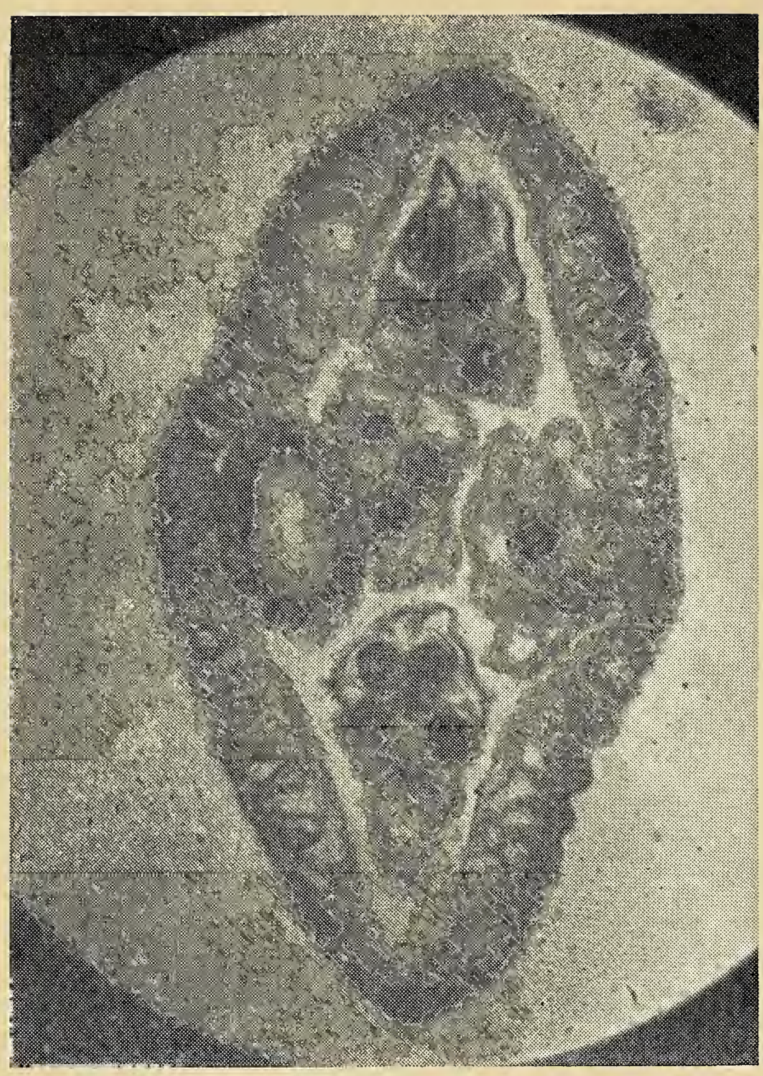

FIG. 4. Photomicrograph of median cross section through an adult female eyeworm.

The cuticular buccal capsule is six-lobed and, as is characteristic of the Thelaziidae, is divided into two chambers, the anterior protostom and the posterior mesostom. The esophagus is of the typical spirurid type and is approximately 1.5 mm. in length. It is distinctly divided into a short anterior muscular portion and a posterior glandular portion. The lumen is restricted and triradiate when viewed in cross section. A well-developed esophageal-intestinal valve separates the esophagus from the intestine.

The thin-walled intestine extends almost the entire length of the body, varying only slightly in diameter, and joins the esophagus anteriorly and the rectum posteriorly. The intestinal wall is composed of a single layer of short, ciliated columnar cells. The rectum is thick-walled and muscular and terminates at the ventral anus in the case of the female. In the male, the ejaculatory duct joins the rectum ventrally to form the cloaca.

The excretory system is of the simple H or oxyuroid type. From the ventral pore the common excretory duct extends dorsally through the large excretory cell and divides on the ventral side of the esophagus to join the two lateral excretory canals. These lie embedded in the lateral lines of the body wall. The lateral lines, which extend almost the entire length of the body, are, apparently, each a single large multi-nucleate cell. The lateral canals terminate posteriorly at the laterocaudal papillae.

A nerve ring surrounds the esophagus, cephalic of the excretory pore. In association with it are four large ganglia, two dorsal and two ventral, and a number of smaller cells. A dorsal and a ventral nerve cord extend posteriorly the length of the body, and several smaller nerve fibers extend into the cephalic region.

The mature male possesses two spicules of unequal length, both of which are cuticular in nature, transversely striated, and hollow. The shorter, which is "trough-shaped," meaures about 200μ in length by 30μ in maximum width, is only slightly protrusible, and acts primarily as a guide for the longer, more slender spicule. The long spicule is 3 to 4.2 mm. in length by 10μ in maximum width and is capable of being protruded from the cloaca almost its entire length. A short muscular ejaculatory duct extends anteriorly from the cloaca and terminates in a thin-walled seminal vesicle, an uncoiled organ extending over half the length of the body. The single long, coiled testis fills the remainder of the body cavity.

In the female the vulva, which measures 46 to 51μ in diameter, is located ventrally in

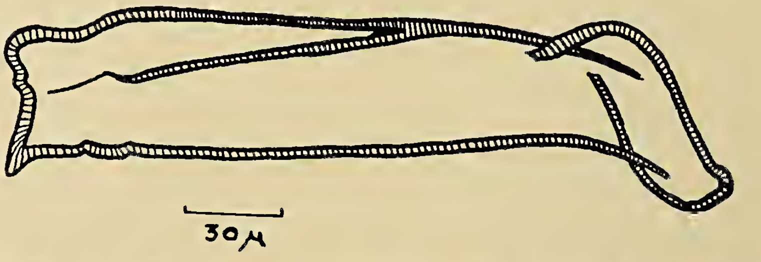

FIG. 5. The short, "trough-shaped" spicule of the adult male eyeworm.

the posterior half of the body. It is surrounded by a cuticular ring of highly refractile material. The vagina extends anteriorly from the vulva and is divisible into two parts, by reason of the thickness of the wall. The proximal portion is nearly 150 μ in length and 35 μ in diameter. The distal thicker-walled portion is approximately 60 μ in diameter. The vagina branches to form the two thin-walled uteri. These extend forward to the posterior region of the esophagus, where they reflex and extend back to the region of the vulva. The diameter of the uteri decreases to 22–30 μ to form the two ovaries which lie as a coiled mass in the posterior portion of the body cavity.

HOSTS OF THE EYEWORM

Nematodes inhabiting the eyes of birds have been reported from a number of species. Most of these parasites are members of the genera *Thelazia* and *Ceratospira*, or are species of the genus *Oxyspirura* other than *O. mansoni*.

The hosts of only those eyeworms which have been definitely identified as *Oxyspirura mansoni* (or *parvovum*) are recorded here.

Definitive hosts

Manson's eyeworm has been reported to occur naturally in the following birds: domestic chicken (*Gallus domesticus*) (Cobbold, 1880); turkey (*Meleagris gallopava*) (Cram, 1927); peafowl (*Pavo cristatus*) (Magalhaes, 1888); English sparrow (*Passer domesticus*) (Illingworth, 1931; Alicata, 1947); mynah bird (*Acridotheris tristis*) (Alicata, 1947); Chinese dove (*Streptopelia chinensis*) (Alicata, 1947; Schwartz and Schwartz, 1949); Japanese quail (*Coturnix coturnix japonica*) (Schwartz and Schwartz, 1949); pheasant (*Phasianus torquatus torquatus* and *P. vesicolor vesicolor*) (Schwartz and Schwartz, 1949).

Through the cooperation of Paul Breese, Director, the birds in the Honolulu Zoo are being examined for the presence of *Oxyspirura mansoni*. This survey is not complete as yet, but the following new hosts may be recorded: the great Argus pheasant (*Argusianus argus argus*) and the Siamese fireback pheasant (*Diardigallus diardi*).

Role of the natural reservoir hosts in the spread of the parasite in Hawaii

During the course of this investigation mynah birds, English sparrows, and Chinese doves have been trapped on the University campus and have been found to harbor Manson's eyeworm. Similar observations have been made by other investigators in other parts of Hawaii (Illingworth, 1931; Alicata, 1947; Schwartz and Schwartz, 1949; Tanada, personal communication).

TABLE 3
NUMBERS OF INFECTIVE LARVAE PER ROACH
(100 SURINAM ROACHES EXAMINED AT EACH LOCALITY)

STAGE	RANGE	MIYATA POULTRY FARM, WAIALAE, OAHU	UNIVERSITY FARM, MANOA VALLEY, OAHU*	WAIKIKI, OAHU†
Adult roaches	Max. Min. Ave.	36 16 23	3 0	None
Nymphs (Final instar)	Max. Min. Ave.	34 1 3	2 0	None
Young nymphs	Max. Min.	6 0	0 0	None

*Roach population low (daily removal of manure, weekly chlordan spray).
†Approximately 4 miles from nearest poultry farm.

Since these commonly infected birds are widespread and numerous throughout the Hawaiian Islands, it seemed desirable to ascertain the role they play in the dissemination of the parasite. To determine this, the degree of infestation of Surinam roaches was established at (1) a heavily infested poultry farm in Waialae, Honolulu, Oahu; (2) a relatively clean poultry yard in Manoa Valley, Honolulu; and (3) a residential area in Waikiki, Honolulu. In all three places roaches were numerous.

As shown in Table 3 the roaches from (1) harbored a large number of infective eyeworm larvae per roach. At (2), where low infestation of the chickens resulted from strict sanitation and frequent removal of the manure, but where large numbers of wild birds gathered to feed, the number of larvae per roach was very low. At (3), an area at some distance from any poultry farm, but where wild birds were also very numerous, no larvae were found in the many roaches examined.

Inasmuch as domestic fowl and wild birds are the only sources of infection of the local roaches these data indicate that the local wild birds are of little importance as reservoir hosts in the dissemination of the eyeworm population. Apparently their feces are too scattered to be eaten to any great extent by the roaches.

Mammals as hosts of Manson's eyeworm

In no case has *Oxyspirura mansoni* been known to occur naturally in the eyes of a mammal. Fielding (1927) found that infective eyeworm larvae placed in the eyes of guinea pigs would develop to maturity.

To check Fielding's observations on another mammal, I obtained several white rats. Each of these was forcibly fed four infected roaches. The next day the eyes were anesthetized with a 5 per cent solution of butyn and examined carefully for eyeworm larvae. No larvae were found.

Approximately 30 infective larvae were then introduced by pipette into the mouth of one of the rats. On examination of the eyes 24 hours later, no larvae were found.

Two rats then received approximately five eyeworm larvae per eye. One was examined after 10 days and larvae were seen in both eyes. The rat was necropsied and the worms were removed. They had molted to the fourth stage and the reproductive organs were developing normally. The second rat was killed 25 days after the larvae were placed in its eyes. Adult male and female worms were recovered from both eyes.

LIFE HISTORY OF THE PARASITE

Apparently little effort had been made before about 1927 to ascertain the life cycle of *Oxyspirura mansoni*. Previously Emmerez and Megnin (1901), and Emmerez (1918), Ransom (1904), and Ozoux (1910) had attempted to transmit the infection directly from one chicken to another with embryonated eggs and/or first-stage larvae; but they carried the work no further when their efforts were unsuccessful.

Kobayashi (1927) in Formosa and Sanders (1928) in Florida found that an intermediate host, which they identified as the cockroach *Pycnoscelus surinamensis* Linn., was essential for the completion of the life cycle of the parasite. Previously Fielding (1926) had shown the same roach to be the intermediate host of the Australian eyeworm of poultry, *Oxyspirura parvovum* Sweet. Fielding (1927 and 1928*a*) studied the developmental anatomy of the Australian eyeworm, but because of his uncertainty as to whether the species was *O. mansoni* or *O. parvovum*, he referred to it simply as the eyeworm of poultry in his latter paper. The validity of *O. parvovum* as a species was questioned by Tryon (1926). This lack of clarity as to species, together with the fact that Fielding's drawings were not identifiable with the material found in Hawaii, led me to investigate the life history of Manson's eyeworm under Hawaiian conditions.

Life cycle in general

The eggs of the parasite are laid by the

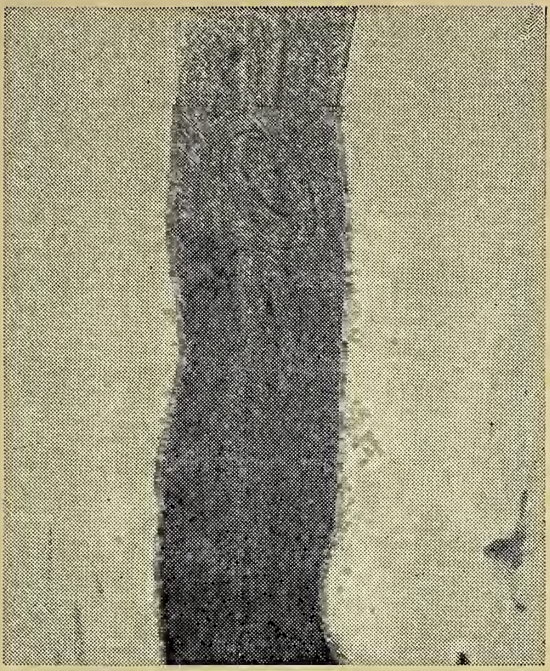

FIG. 6. Photomicrograph of the vagina of a gravid female eyeworm showing embryonated eggs.

adult females in the eyes of the definitive host. They are washed down the naso-lacrimal ducts with the eye fluid into the mouth, swallowed, and finally passed out with the excrement. The intermediate host is infected by eating embryonated eggs or first-stage larvae in the feces of infected birds. After a developmental period of approximately 51 days in the roach, the larvae are infective to the definitive host. They gain entrance when the host roach is consumed by a suitable bird. The larvae seldom pass farther than the crop of the definitive host (Fielding, 1926), where they migrate from the tissues of the roach under stimulation of heat and moisture.

The infective larvae then crawl up the esophagus, reach the roof of the mouth, and gain entrance to the eyes through the naso-lacrimal ducts. During this study worms have been observed in the eyes of a chicken within 5 minutes after the ingestion of an infected roach.

The eyeworm eggs

During the course of this study several attempts were made to recover embryonated eggs from the eyes of infected birds. Fluid was removed from the eye with a pipette and examined beneath the microscope, but in no case were eggs observed. However, they were recovered in varying quantities from the crop, intestinal contents, and feces of infected birds. The eggs were elliptical in shape, had a shell thickness of 1 to 1.5μ, and were approximately the same size as those measured in the

TABLE 4

REPORTED MEASUREMENTS OF EYEWORM EGGS (ALL MEASUREMENTS IN MICRONS)

STAGE	RANGE	SCHWABE (Oahu, T.H.) 1948–49	RANSOM (Florida) 1904	SWEET (Australia) 1910*	FIELDING (Australia) 1928†	FIELDING (Australia) 1928*
Embryonated eggs from feces	Max.	60x45				
	Min.	42x23				
	Ave.	53x40				
Embryonated eggs from vagina and uteri	Max.	50x28.5	65x45	45x30		
	Min.	35.7x17.8	50x40	33x25		
	Ave.	41.6x23.7			43x31	41x30
Shelled, segmented eggs from uteri	Max.	42.9x32				
	Min.	28.4x14.3				
	Ave.	36.7x22.9				
Unshelled, non-segmented eggs from uteri	Max.	28.25x10.7				28x14
	Min.	21.6x7.2				24x12
	Ave.	23.4x9.5	24x12			

**O. parvovum.*

†Old fixed *O. mansoni* eggs.

vagina of gravid female worms (Table 4). The shell had a smooth surface with no discernible markings.

Ransom (1904) obtained embryonated eggs from the uteri of gravid worms. These were placed in "salt solution" and were reported to have hatched in 3 days. The larvae obtained were dead, or were feeble and soon died. Sanders (1928) employed a similar technique, substituting distilled water for the saline solution, and found that embryonated eggs from gravid females hatched in 3 days.

Fielding (1927) succeeded in hatching living larvae in the following media: 0.9 per cent NaCl, 1.4 per cent NaCl, other physiological solutions, 1 per cent citrated fowl blood, moistened earth, fowl feces (plus sand and saline), sterile fowl feces (plus saline and charcoal), moistened bread. Hutson (1943) was unsuccessful in hatching eggs in distilled water but obtained living first-stage larvae from cultures of distilled water plus fowl feces. Upon introduction into the body cavity of a roach these larvae developed normally.

It seemed desirable to determine, if possible, whether eyeworm eggs hatch more readily in the digestive tract of the intermediate host or in fowl feces. Attempts were made to obtain mature eggs from the crops of infected chickens. (Some embryonated eggs obtained from the uteri of gravid worms may not be fully matured. Such eggs in other species of nematodes have been known to "hatch" abnormally in artificial media.) Although eggs were usually present in the crop, they could not be separated in sufficient quantity for the experiment. This made it necessary to obtain embryonated eggs from macerated female worms. To avoid as far as possible the selection of immature eggs, special care was taken to collect by use of a fine pipette only the largest eggs.

These were placed in three dishes containing (1) physiological saline solution, (2) physiological saline solution plus sterilized fowl feces, and (3) physiological saline solution plus the macerated alimentary tracts of several Surinam roaches. None of the eggs had hatched by the end of the second day, but quiescent or feeble larvae were observed in each of the three cultures on the third day. None of the larvae survived. Although additional work is indicated, apparently, under the conditions of this experiment, the medium had no appreciable effect upon the rapidity with which eyeworm eggs hatched.

Larvae observed both in the artificial media and in the alimentary tract of the intermediate host apparently hatched in the following manner. (The terminology used is based on the description of the spirurid egg by Christenson in Chitwood *et al.*, 1940.) The chitinous middle layer of the shell separated from the inner vitelline membrane at either or both poles. The region of the poles then became thinner, producing polar operculations marked by ill-defined sub-terminal lines of fracture. One or both caps either broke off at the line of fracture or dissolved, leaving a barrel-shaped shell, open at either or both ends. The embryo then freed itself from the thin vitelline membrane and squeezed through the polar opening.

Similar observations have been made by Ransom (1904), Sanders (1928), and Fielding (1927).

Development in the intermediate host

Eggs were obtained from gravid female worms and were fed to young laboratory-raised roach nymphs. One nymph was dissected 24 hours after feeding, and numerous embryonated and non-embryonated eggs were found in the crop. No eggs or egg shells were found in the feces of the nymphs examined at this time.

At 48 hours, several first-stage larvae were found free in the lumen of the crop and anterior midgut, and many others were observed in the process of hatching. The empty shells were barrel-shaped, which suggested that they hatched by splitting off one or both polar caps, as previously described. Several of the larvae were rather firmly attached to cellular debris by the tip of the tail. Embryonated eggs were found in the midgut until the seventh day, and numerous larvae were present until the ninth day. A single larva was found in the midgut on the eighteenth day. It was almost double the size of those seen there previously.

First-stage larvae were observed for the first time in the body cavity on the eighth day, and by the tenth day many were seen. Some were wandering freely in the cavity, but most were found in the adipose tissue lining the abdominal wall. Apparently they migrated through the wall of the midgut, and after wandering in the body cavity for a short time, burrowed into the abdominal fat. The larvae became lethargic at this stage and were extremely difficult to extricate. They grew only slightly in length, broadened considerably, lost their long, pointed tails, and assumed a more-or-less club-shaped appearance because of the enlargement of the several large rectal cells.

Incomplete encystment actually occurred in this stage in some instances, with the ill-defined cyst measuring approximately 0.3 mm. by 0.5 mm. Thereafter little change took place until about the seventeenth day when larvae measuring 250μ to 320μ in length and with the cuticular sheath loosened at both the anterior and posterior ends were observed. Larvae in this pre-molting condition were seen until the twenty-fifth day, at which time a second-stage larva which measured 990μ in length was observed.

Complete encystment occurred in the second stage of larval development. The cysts were nearly spherical in shape and measured approximately 0.8 mm. by 0.8 mm. They were found attached to the alimentary tract, particularly around the rectum and entangled in the Malpighian tubules. The cysts were thin-walled and transparent. The wall, apparently of loose connective tissue, consisted of a gelatinous matrix and a few scattered cells. The wall was richly tracheated, which constituted evidence that the cyst was formed by the cockroach and not secreted by the parasite. The cysts were filled with fluid and the coiled larvae were able to move about freely in them.

On the thirty-third day encysted second-stage larvae measuring 1.8 mm. to 1.85 mm. were observed; those on the fortieth day had attained a length of 2.6 mm. to 4.5 mm. On the forty-fifth day a second-stage larva 6.62 mm. in length was observed in the process of molting. Ecdysis evidently takes place between the forty-fifth and fiftieth days, at which time the last molting larvae were seen.

Many of the parasites were able to free themselves from their cysts through their increased activity during the period of ecdysis, and on the fifty-first day numerous third-stage larvae were found, some encysted, but most wandering freely in the body cavity. These early third-stage larvae measured from 7.4 mm. to 8.3 mm. in length and were extremely active.

Whether or not those larvae which were unable to free themselves during the molting period eventually escape from the cyst could not be ascertained.

Upon the attainment of the third stage, the larvae were infective to the definitive host, as was shown by their appearance in the eyes of chickens within 5 minutes after they were introduced into the mouth by pipette.

Development in the definitive host

Large numbers of infective larvae were obtained from roaches by use of the Baermann apparatus. They were introduced by pipette into the mouths of 4-week-old chicks. The larvae migrated up the naso-lacrimal ducts and were observed to enter the eyes several minutes after they were introduced. Chicks were killed every 2 days, and the worms were removed from the eyes and examined microscopically.

On the second day the larvae appeared much the same as they did in the cockroach. On the fourth day several third-stage larvae in the process of molting were observed.

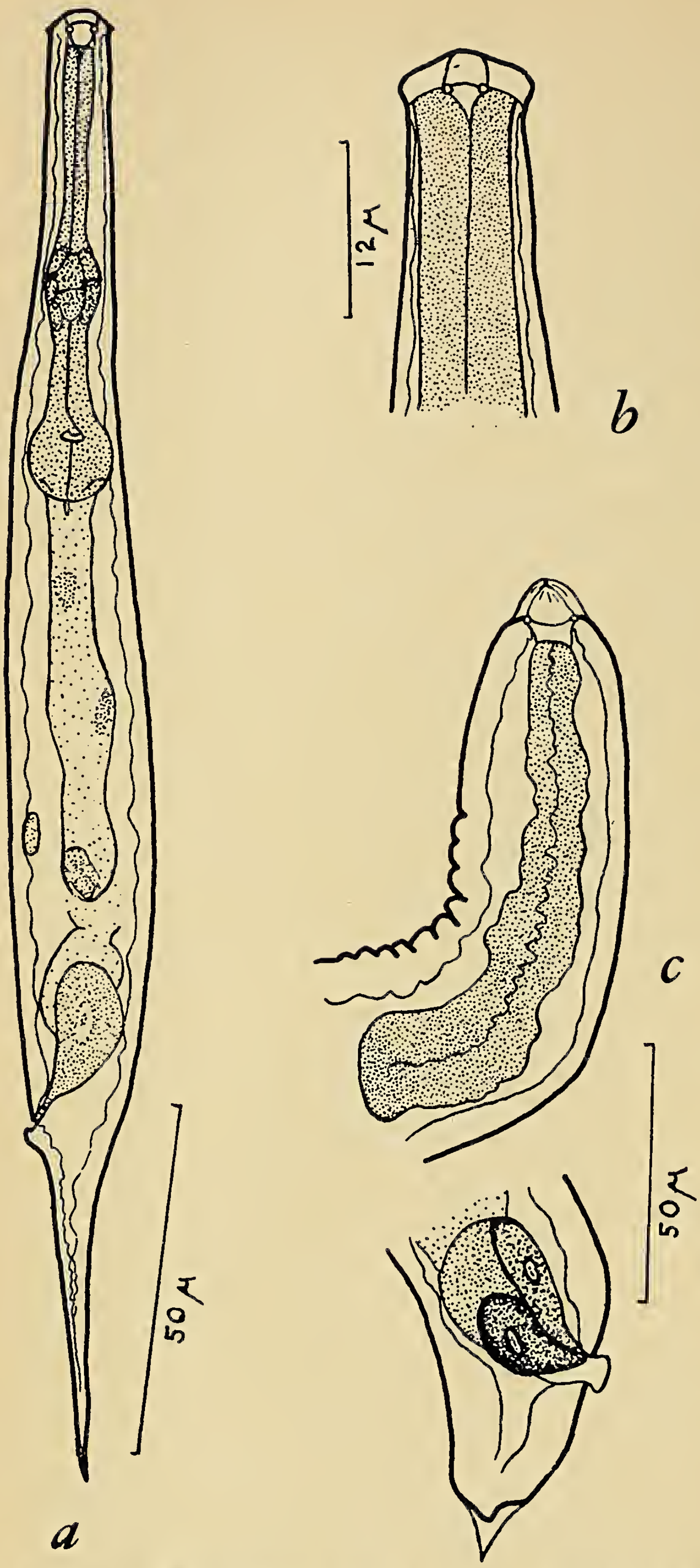

FIG. 7. *a*, First-stage larva; *b*, anterior end of late first-stage larva, *c*, first-stage larva in process of molting, showing loosened cuticle at anterior and posterior ends.

Fourth-stage larvae were first seen on the fifth day, although some third-stage larvae were still present until the seventh day. The reproductive organs developed rapidly during this period: the vulva of the female was apparent on the seventh day and the developing short spicule of the male on the ninth day.

A separate mesostom and protostom had begun to form by the thirteenth day. For most larvae the final molt occurred about the twenty-first day, and young adults were present on the twenty-third day. Embryonated eggs were first observed in the crop contents of a chicken on the thirty-second day. Egg laying apparently began between the thirtieth day, when the previous negative examination was made, and the thirty-second day.

DESCRIPTION OF THE LARVAL STAGES

First-stage larvae

Because of their small size and poor development the various structures of the first-stage larvae were discerned only with difficulty. The newly hatched larvae were long and slender, being somewhat attenuated at the anterior and posterior ends. The anterior end was rather blunt and the relatively long tail was acute. In the later period of this stage, the tail shortened considerably, the relative growth in width exceeded the growth in length, and the body assumed a more-or-less club-shaped appearance because of the enlargement of the several large rectal cells. The maximum size observed in this stage was a length of 339μ and a width of 24.9μ. (See Table 5. Tables 5, 6, 7, and 8 show detailed measurements of a single typical larva for each of the days recorded. When size variations among the larvae on a particular day were significant, detailed measurements of more than one larva are given. When the sex of the larvae could be readily determined, measurements of both male and female larvae for a particular day were made.)

The cuticle was very thin and transparent and bore fine transverse striations. No papillae were apparent in this stage.

The oral opening was surrounded by a ring of highly refractile material. The transparent esophagus extended approximately one-third the length of the body and terminated as a large spherical bulb, possessing what appeared to be an esophageal valve. The intestine consisted of a number of rather large, ill-defined cells containing numerous large vacuoles of lipid-like material. The ventral anal

TABLE 5
MEASUREMENTS OF FIRST-STAGE LARVAE (ALL MEASUREMENTS IN MICRONS)

MEASUREMENTS	DAYS AFTER INFECTION				
	3	5	8	17	18
Length	125	174	207	249	286
Width (ant. end)		7	7	7.5	7
Esophagus length		57.1		107	93
Anus to post. end		49.9	46.4	39.2	32.2
Width (max.)	14.3	17.8	17.8	32	18

aperture was often seen with a posterior cuticular fold partially covering it, and a few large rectal cells (apparently three in number) were well developed.

A nerve ring was seen encircling the esophagus at approximately two-thirds of the distance from its anterior end.

Neither an excretory pore nor an excretory cell was apparent in this stage.

A minute genital primordium, approximately 75 μ from the posterior end, was visible on the ventral body wall in several living specimens.

Second-stage larvae

Rapid growth occurred during this stage of larval development. The length increased from 990 μ in early second-stage larvae to 6.62 mm. in the latter portion of the stage. The larvae were long and slender with tapering tails, on the end of which four small papillae were discernible in the later part of the stage.

The cuticle was relatively thin and bore marked transverse striations. A provisional buccal capsule had begun to form, but no cephalic papillae were visible.

The esophagus was long and slender and in the late second stage extended approximately one-half the length of the body in some larvae. Two gland-like structures were apparent at its anterior end, and the esophageal-intestinal valve was well formed.

The intestine was a well-defined, thin-walled tube, varying only slightly in diameter and extending from the esophagus to the rectum. The cellular structure of its wall was apparent.

There were three large rectal cells and several smaller ones immediately anterior to the anus, which was located ventrally approximately 170–190 μ from the posterior end.

TABLE 6
MEASUREMENTS OF SECOND-STAGE LARVAE

MEASUREMENTS	DAYS AFTER INFECTION				
	27	33	40	40	45
Length	999.6	1.85*	2.6*	4.5*	6.62*
Width (ant. end)	54	53.5	38.5	62	52
Width (middle)	67.8	89	107.8	170	172
Width at anus		24	92.4	77	85
Esophagus length		357	400	616	749
Esophagus width (post. end)				43	
Anus to post. end	53.5	160	170	246	250
Excretory pore to ant. end		178		250	360.5
Nerve ring to ant. end		89		160	185.6
Intestine width			62	112	
Genital primordia to post. end				890	

*These measurements in millimeters; all others in microns.

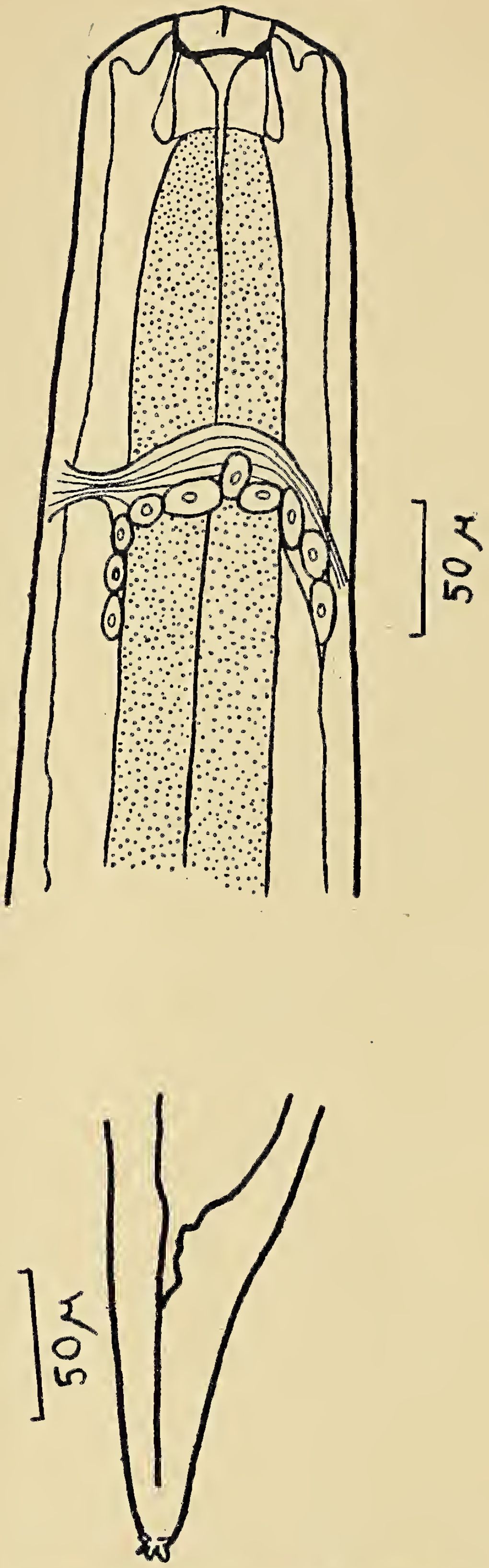

FIG. 8. Anterior and posterior ends of late second-stage larva.

An excretory pore and a large excretory cell were plainly visible on the ventral side of the esophagus, 250–300 μ from the anterior end.

The nerve ring and several small ganglion cells encircled the esophagus, about 100 μ anterior to the excretory pore.

The genital primordium was visible in the living larvae ventrad of the intestine, approximately 500 μ from the anus.

Third-stage larvae

Third-stage larvae varied from 7.53 mm. to 8.31 mm. in length and had a maximum width of approximately 157 μ. Other than in this feature, their over-all appearance was much the same as that of the second-stage larvae.

The cuticle was smooth and no striations were discernible, either transverse or longitudinal. The anterior oral opening was six-lobed, and four sublateral papillae were plainly visible projecting at right angles to the surface. No caudal papillae were present in this stage.

The esophageal gland-like structures apparent in the second stage were not discernible in the third-stage larvae, but a number of cells were seen to surround the esophagus at its anterior end. The esophagus was distinctly divided into an anterior muscular portion having a length of about 210 μ and a posterior glandular portion approximately 600 μ in length. The remainder of the alimentary tract appeared much the same as that of the second-stage larvae.

TABLE 7

MEASUREMENTS OF THIRD-STAGE LARVAE*

Days after infection	51*
Length†	7.53–8.31
Width (ant. end)	53.5
Width (max.)	157
Width (at anus)	92.3
Buccal capsule length	35.7
Esophagus length	846
Esophagus width (post. end)	71.5
Intestine width (max.)	107
Nerve ring from ant. end	178.5
Excretory pore from ant. end	303
Anus to post. end	184

*In intermediate host. For measurements of third-stage in definitive host, see Table 7.

†This measurement in millimeters; all others in microns.

In addition to the excretory pore and cell apparent in the second stage, two lateral excretory canals were traced from the region anterior of the excretory pore to very near the tip of the tail. Each canal sent off an anterior branch which joined ventrad of the esophagus and entered the excretory cell as a common excretory duct. The lateral canals

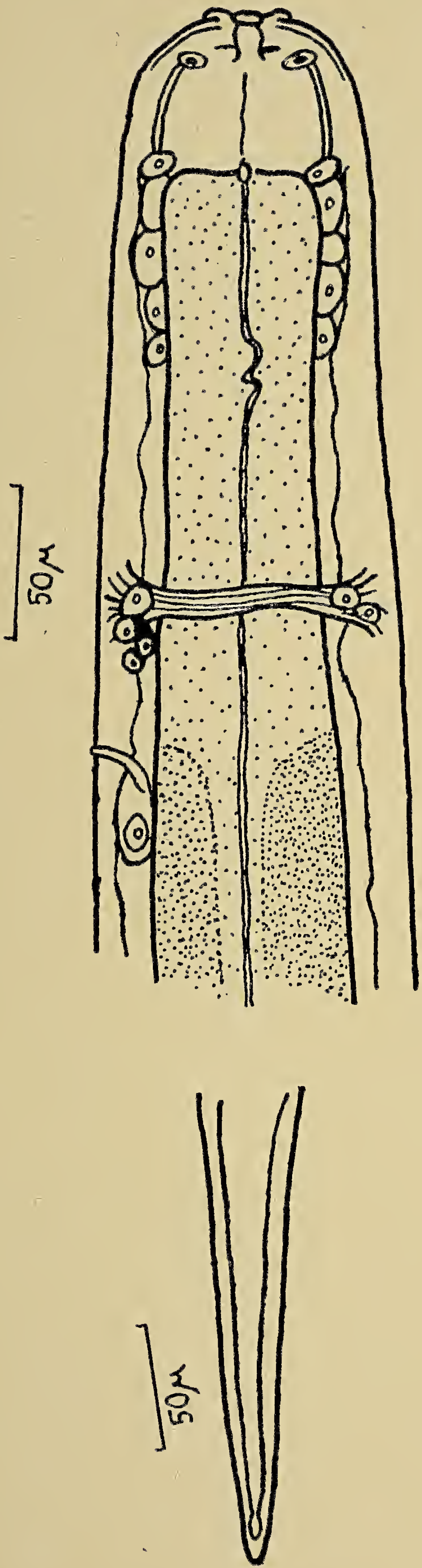

FIG. 9. Anterior and posterior ends of third-stage larva.

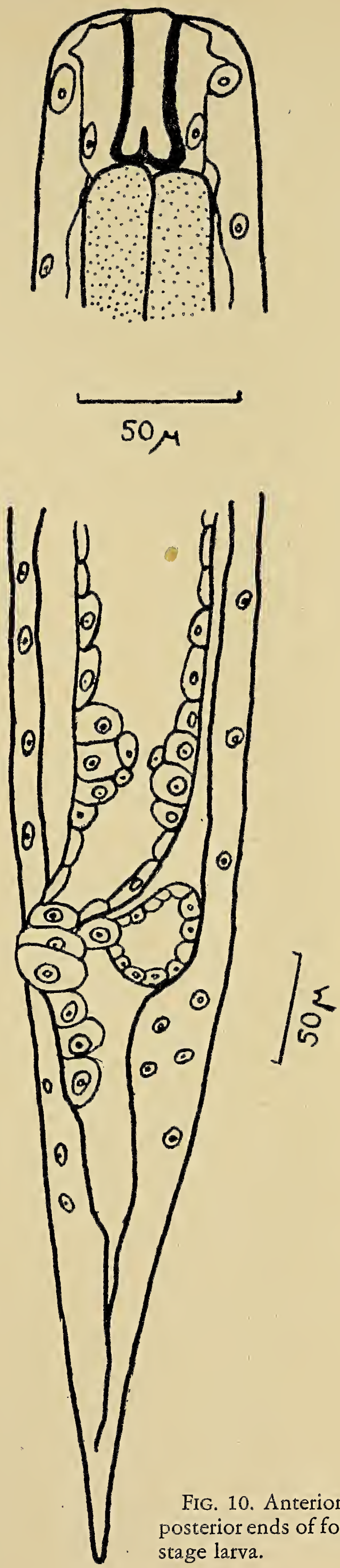

FIG. 10. Anterior and posterior ends of fourth-stage larva.

TABLE 8

MEASUREMENTS OF THIRD- AND FOURTH-STAGE LARVAE IN THE DEFINITIVE HOST

MEASUREMENTS	DAYS AFTER INFECTION														
	THIRD STAGE		FOURTH STAGE												
	2	4	5	5	7	9	11	11	13	16	18	18	21	21	23
	—	—	♀	♂	♀	♀	♀	♂	♀	♂	♀	♂	♀	♀	♀
Length*..........	8.23	10.38	10.38	10	12.08	10.1	10.3	9.7	12.1	11.4	12.6	10.4	12.3	14	12.8
Width (middle)...	257	250	222	176	250	214	303	267	267	326	307	284	293	290	310
Width at vulva....							176		183		185		204	196.5	196
Width at anus....	89.4	87	89.4	92.8	100	87	92.8	103	104	100	100	110	100	92.8	92.8
Oral opening width	35.7	35.7	32	32	35.7	40	32	28.6	32	35.7	24	21.4	21.4	28.6	35.7
Buccal capsule length.........	42.9	54	42.9	50	47	50	50	42.9	47	42.9	45	40	57.2	57.2	35.7
Esophagus length (ant. portion)...		340	250	330	330	287	267	330	287	267	250	267	293	304	271
Esophagus length (total).........	930	1,285	1,039	1,150	1,212	1,032	1,140	1,080	1,230	1,060	1,039	1,140	1,220	1,230	1,054
Esophagus width (post. end).....	62	77	85	100	92.8	92.8	85	85	92.8	100	92.8	92.8	96.5	92.8	103.5
Nerve ring to ant. end........	250	268	214	287	287	234	228	275	234	172	226	214	222	279	214
Excretory pore to ant. end........	357	392	303	303	392	303	326	360	357	330	342	307	357	379	307
Intestinal width (max.).........	89.4	71.4	89.4	77	77	75	96	96	81	73	54	68	74	71	71.4
Vulva to post. end.					1,130	850	784		950		950		910	883	1,000
Anus to post. end.	340	357	340	392	430	330	357	392	370	330	370	340	340	360	392

*These measurements in millimeters; all others in microns.

were each embedded in a multinucleate lateral line 50 μ in width.

The nervous system appeared much the same as in the second-stage larvae.

The sexes could be distinguished readily in the third stage. In the female the genital primordium could be seen attached to the ventral body wall approximately 650 μ from the posterior end. In the male the primordium was similarly situated but unattached. The primordium in both sexes measured approximately 35 μ by 14 μ in this stage and was composed of several cells.

Fourth-stage larvae

In general proportions the fourth-stage larvae differed little in appearance from those of the third stage. Early fourth-stage larvae measured about 10 mm. in length while those in the later portion of the stage measured from 12.8 to 14 mm.

Fine transverse striations were evident in the transparent cuticle. The four sublateral papillae each measured approximately 4.6 μ in length. In addition, by the twenty-first day, the two latero-caudal papillae had begun to form, and the preanal and postanal papillae of the males were evident.

By the thirteenth day the separate protostom and mesostom could be differentiated, and in the later part of the stage the buccal capsule appeared much the same as in the adult.

The remainder of the alimentary tract showed little change from that of the third-stage larvae, the intestine being displaced somewhat to allow room for the developing reproductive organs.

The lateral excretory canals were seen to terminate in the latero-caudal papillae in the late fourth-stage larvae. Other than this, the excretory system had apparently achieved its full development by the end of the third stage.

The only additional development noted in the nervous system in the fourth stage was the appearance of two large dorsal and two large ventral ganglion cells near the nerve ring.

In the fourth-stage larvae the greatest development occurred in the reproductive system. By the fourth day the genital primordium in both sexes measured approximately 214 μ in length and in the case of the female was attached to the ventral body wall. The point of attachment, which later became the vulva, was approximately 894 μ from the posterior end. In the male the genital primordium became a U-shaped tube with two terminal bulbous growing tips developing toward the posterior end. By the ninth day the short spicule of the male had begun to form and the vulva of the female was apparent, although it remained closed externally during the entire fourth stage. The reproductive tract, at least in the female, appeared almost complete by the thirteenth day. By the sixteenth day the long spicule of the male could be recognized. The male reproductive system was well formed by the twenty-first day; the ejaculatory duct could be seen to enter the ventral side of the rectum at its posterior terminus, the anal papillae were evident, and both spicules were well developed.

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Viability of Hawaiian Forest Tree Seeds in Storage at Various Temperatures and Relative Humidities[1]

ERNEST K. AKAMINE[2]

INTRODUCTION

IN HAWAII the Territorial Board of Commissioners of Agriculture and Forestry is charged with the maintenance of forest reserves. Before World War II forest tree seeds were imported from outside sources for reforestation purposes. During the war years, when seeds could not normally be imported because of the critical shipping situation, it was realized that some locally harvested tree seeds could not be kept under ordinary conditions for any extended period without impairment of their viability.

At the request of the Territorial Board of Commissioners of Agriculture and Forestry, studies on the viability of forest tree seeds were pursued at the University of Hawaii Agricultural Experiment Station between the years 1944 and 1948. Seeds of the following trees were tested: paper bark (*Melaleuca Leucadendron* Linn.), brush box (*Tristania conferta* R. Br.), turpentine tree (*Syncarpia laurifolia* Ten.), Norfolk Island pine (*Araucaria excelsa* R. Br.), mamani (*Sophora chrysophylla* Seem.), Monterey cypress (*Cupressus macrocarpa* Hartw.), and Indian sandalwood (*Santalum album* Linn.). It is the purpose of this paper to present the results of experiments designed to develop practical means of prolonging the viability of seeds of these forest trees under storage.

It had previously been found that because the prevailing temperatures and relative humidities of the atmosphere in Hawaii are generally high, seeds of garden, field, and forage crops in ordinary storage deteriorated rapidly (Akamine, 1943). It was further determined that, in order to maintain their longevity, seeds should be stored in a medium in which either the temperature or the relative humidity is kept below that of the atmosphere, or, better still, in a medium in which both the temperature and the relative humidity are kept below those of the air.

Germination and viability studies conducted on forest tree seeds have not been as extensive as those conducted on seeds of other species. Cold storage prolonged the life of Noble fir seed (Isaac, 1934). Moss (1938) found that seeds of three species of *Populus* produced a germination of 70 per cent after a storage period of 2 years under calcium chloride at 23° F. These seeds lost their viability in 2 to 4 weeks when they were stored at room temperature (70° F.). Coniferous seeds have been successfully stored for several years in sealed containers at 36° to 40° F., provided the moisture content of the seeds did not exceed 5 to 8 per cent (Heit and Eliason, 1940; Latour, 1942). The literature on viability studies of forest tree seeds has been reviewed by Toumey and Korstian (1931: 109–152) and by Baldwin (1942: 81–94). More recently Crocker (1948: 28–66) and Porter (1949) also reviewed the work on storage studies of seeds, including those of forest trees.

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EXPERIMENTAL PROCEDURE

The seeds of the seven forest tree species used in these studies were harvested and collected from the various forest reserves throughout the Territory by the foresters of the Territorial Board of Commissioners of Agriculture and Forestry. The viability studies were conducted by the Department of Plant Physiology at the University of Hawaii Agricultural Experiment Station. Freshly harvested and cured seeds were used. Species and their storage periods are listed in Table 1.

Because of the difficulty encountered in most of the species in separating normal embryonated seed from empty seed by external appearance the "per cent normal seed" for each species was determined from internal examination of lots of known numbers of seeds obtained at random (Table 1). Germination tests were conducted on lots of seed counted out at random, and the percentage of germination was based on the "per cent normal seed."

Seeds were stored at relative humidities of approximately 30, 45, 60, 75, and 90 per cent at temperatures of 45°, 59°, and 70°–80° F. (room temperature).[3] The required humidities were maintained with solutions of sulphuric acid of various concentrations (Akamine, 1943) in large desiccators. Some seeds of each species were stored in airtight containers without humidity control at each temperature, and control lots of seeds stored in the open were also included under each temperature. At intervals during the storage period, the specific gravity of the sulphuric acid solutions was determined with a hydrometer, and any divergence from the required specific gravity was corrected by the addition of water or concentrated sulphuric acid.

At the time of storage, an initial germination test was conducted on the seeds of each species. Thereafter, germination tests were conducted at intervals, once in approximately 1 to 2 months, at the beginning of the storage period, and once in approximately 6 months, during the latter part. Data on the germination test period, germination condition, number of replications, and number of seeds per replication for seeds of each species are shown in Table 1. In all cases, tap water was used in the substratum. The sandalwood seed, with its seedcoat removed by hand, was treated with a fungicide ("Thiosan"). The seedcoat was removed to hasten germination, and the fungicide was applied to prevent the contamination of the germination medium by mold organisms. Before testing them, the seeds of mamani were mechanically scarified for 2 to 3 minutes in a shaking machine (Akamine, 1942), using an equal amount of black sand and seed. The black sand was used to abrade the seedcoat, which in this seed is impervious to water and hence requires scarification in order for the seed to germinate. The few hard unswollen seeds remaining at the end of the germination test were nicked on the seedcoat with a knife and left for an additional period to germinate. In all cases, all sound ungerminated seeds left at the end of the test were considered viable and included in calculation of the germination percentage. Because of their enormous size, the seeds of Norfolk Island pine were germinated in a Minnesota seed germinator at room temperature instead of in the petri dish. The criterion of germination was the emergence of normal primary roots and shoots.

EXPERIMENTAL RESULTS

For the sake of brevity, the voluminous germination data on the stored seeds have been omitted in this paper, and, in their place, graphs[4] constructed from these data are presented in Figures 1 to 7. To present the trend of the germination more readily, the curves for these graphs were drawn from points ob-

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[3] The cold storage facilities of the United States Department of Agriculture Bureau of Entomology and Plant Quarantine at Honolulu, T. H., were used during the early stages of this study.

[4] The author is indebted to Herbert Sakamoto for the construction of the graphs.

TABLE 1
DATA ON STORED SEEDS OF FOREST TREE SPECIES

COMMON NAME	SCIENTIFIC NAME	STORAGE		NORMAL SEED	GERMINATION TEST			
		STARTED	CONCLUDED		TEST PERIOD	GERMINATION CONDITION*	NO. OF REPLICATIONS	NO. OF SEEDS PER REPLICATION
				per cent	*weeks*			
Paper bark	*Melaleuca Leucadendron* Linn.	May 5, 1944	May 5, 1948	19.1	2	Petri dish	4	200
Brush box	*Tristania conferta* R. Br.	May 5, 1944	May 5, 1948	22.3	2	Petri dish	4	200
Turpentine tree	*Syncarpia laurifolia* Ten.	May 5, 1944	May 5, 1948	42.4	2	Petri dish	4	200
Norfolk Island pine	*Araucaria excelsa* R. Br.	Sept. 26, 1944	Nov. 26, 1945	41.0	3	Germinator	4	50
Mamani	*Sophora chrysophylla* Seem.	Dec. 12, 1944	June 12, 1948	100.0	4	Petri dish	4	25
Monterey cypress	*Cupressus macrocarpa* Hartw.	Jan. 24, 1945	June 24, 1948	6.0	4	Petri dish	4	200
Indian sandalwood	*Santalum album* Linn.	July 18, 1945	June 18, 1948	100.0	3	Petri dish	2	10

*All tests at room temperature (70°–80° F.).

tained by the use of "running averages" of the original data.

Paper bark seed

The germination behavior of this seed in storage at various temperatures and relative humidities is graphically presented in Figure 1. At each storage temperature, the relative humidity has influenced the viability of the stored seed (Fig. 1). In general, the lower the humidity, the longer the seed is kept in a germinative condition. At room temperature, the 45 per cent relative humidity gave results slightly superior to the 30 per cent relative humidity. At 59° F., these two humidities were equally effective in prolonging the life of the seed. The 45 and 60 per cent relative humidities were slightly more effective than the 30 per cent relative humidity for maintaining the viability of the seed in storage at 45° F. At each storage temperature, the seed kept in an airtight container maintained its viability just as well as that kept at 75 per cent relative humidity. The longevity curve for the seed stored open at room temperature lies approximately midway between the 60 and 75 per cent relative humidity curves. Since the relative humidity of the air is approximately 68 per cent, it seems logical to assume that the curve for the open storage should be in this position. Although no attempt was made to maintain the humidity in the cold chamber and no humidity measurements were made, it may be surmised that seed stored open at 59° F. was subjected to relative humidities in the neighborhood of 30 and 45 per cent because the curves for these storage media lie in about the same plane (Fig. 1). At 45° F., the curve for the open storage lies in the neighborhood of the lower humidity storage curves after the first year of storage.

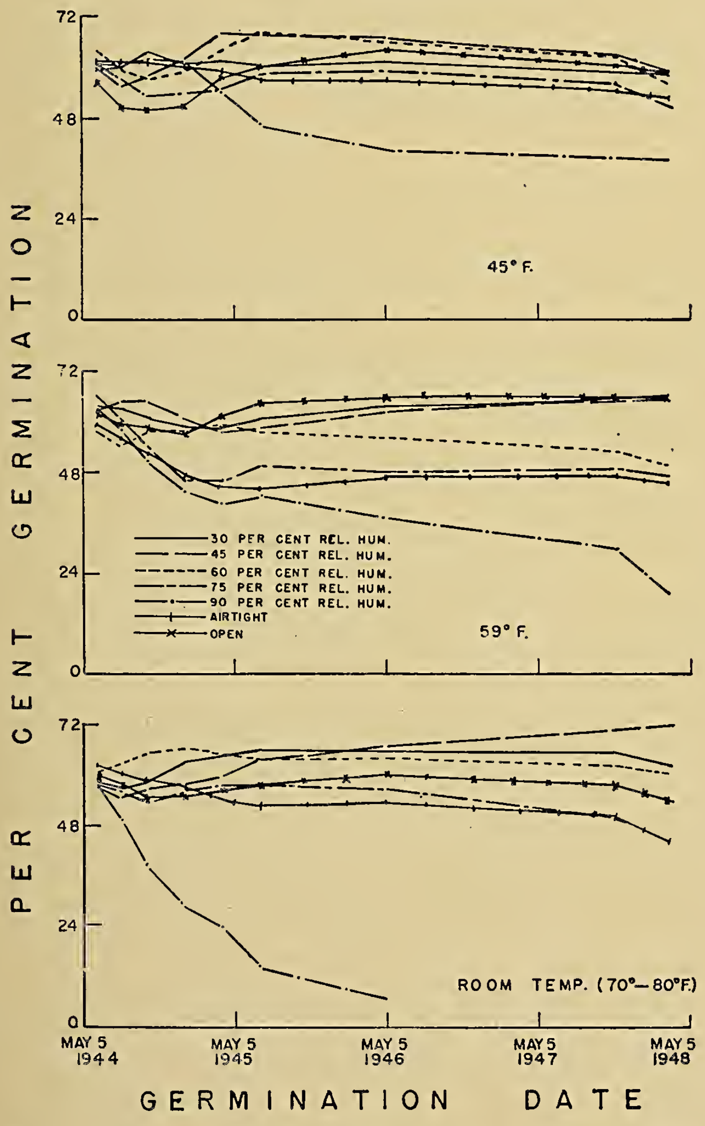

FIG. 1. The effect of temperature and relative humidity on the viability of stored paper bark seed.

When the graphs in Figure 1 are superimposed and a critical examination is made of them, it becomes evident that the effectiveness of the two lowest relative humidities (30 and 45 per cent) in preserving the viability of the seed was not influenced by the different storage temperatures. At relative humidities of 60 and 75 per cent and under airtight conditions, 45° F. and room temperature were each equally more effective than 59° F. in preserving the life of the seed. At a relative humidity of 90 per cent, 45° F. was more effective than 59° F., which in turn was more effective than room temperature in maintaining the longevity of the seed. In open storage, 59° F. maintained the viability of the seed more effectively than 45° F. and room temperature, which were equal to each other in effectiveness.

It can be seen from Figure 1 that the viability of the seed of paper bark could be maintained for about 4 years even in open storage at room temperature. The optimum storage condition at room temperature, however, was one in which the relative humidity was kept below that of the air. Generally speaking, at temperatures of 59° and 45° F., open storage was about as effective as the low relative humidities in preserving the life of the seed.

Brush box seed

The germination behavior of the seed of brush box in storage under various conditions is depicted graphically in Figure 2. In general, regardless of the storage temperature, seeds stored at the low relative humidities maintained their viability better than those stored at the high humidities (Fig. 2). At each temperature, the 45 per cent relative humidity was optimum, being superior even to the 30 per cent. The difference between these two humidities in their effectiveness in increasing the longevity of the seed, however, became smaller as the storage temperature was lowered. At room temperature, the germination curve of the seed stored in airtight containers approached that of the seed in the 60 per cent relative humidity storage toward the latter part of the storage period. With prolonged storage at 59° F., the airtight storage curve was near the 30 per cent relative humidity storage curve. At 45° F., the airtight storage was surpassed only by the 45 per cent relative humidity storage in effectiveness in maintaining the viability of the seed. As in the case of the paper bark seed (Fig. 1), the germination curve of the seed stored open at room temperature lies approximately midway between the curves of the 60 per cent and 75 per cent relative humidity storage (Fig. 2). At 59° F., the open storage curve again lies between the 60 and 75 per cent realtive humidity curves, but at the end of the storage period, it had approached the curve of the higher one of these humidities. At 45° F., the open storage curve actually lies below that of the 75 per cent relative humidity curve.

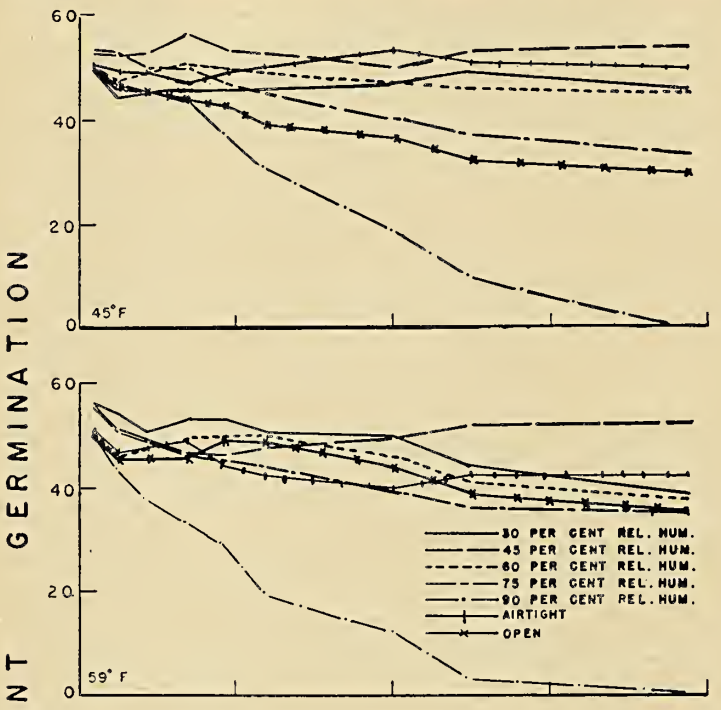

FIG. 2. The effect of temperature and relative humidity on the viability of stored brush box seed.

When the graphs in Figure 2 are superimposed, it is seen that when the seeds were stored at 30 per cent relative humidity, 45° F. was more effective than 59° F. and room temperature in maintaining the viability of the seeds. The two latter temperatures were about equally effective in this respect. The effectiveness of the 45 per cent relative humidity in prolonging the germinative power of the seed was not influenced by the different temperatures employed. At relative humidities of 60 and 90 per cent and in airtight storage, it was found that the lower the storage temperature, the longer the seeds remained viable. Temperatures of 45° and 59° F. were equally more effective than room temperature; in open storage seeds kept at 59° F. remained in a viable state longer than those kept at 45° F. Seeds stored open at the latter temperature in turn kept better than those stored at room temperature.

Since the longevity of the seed at 45 per cent relative humidity was the same at any storage temperature and since this humidity was the optimum for seed storage, it followed that even at room temperature, the seed of brush box could be kept viable for several years provided it was stored at this humidity. Another effective method of prolonging the life of the seed was to store it in airtight containers at 45° F. (Fig. 2).

Turpentine tree seed

The germination results of this seed in storage under various conditions are shown in Figure 3. Seeds stored at different relative humidities behaved differently at different temperatures. In general, at room temperature, the lower the humidity the better the seed kept, although toward the latter part of the storage period, the 45 per cent relative humidity seemed somewhat superior to the 30 per cent humidity. After a prolonged storage period at room temperature, the viability of the seeds in airtight and open storage was approximately the same, and the germination curves for these seeds lie above the 75 per cent relative humidity curve and below the 60 per cent humidity curve (Fig. 3). Seeds stored at relative humidities of 30, 45, and 75 per cent maintained their original germination after 4 years of storage at 59° F. Storage at a relative humidity of 60 per cent and storage in airtight and open containers were slightly less effective than the above humidities at this temperature. Storage at 90 per cent relative humidity at 59° F. was detrimental to the keeping quality of the seed. With prolonged storage at 45° F., relative humidities of 45 and 75 per cent seemed to be about the optimum media for maintaining the longevity of the seed; relative humidities of 30 and 60 per cent and airtight storage seemed to be the next best storage media. Open storage at this temperature was slightly inferior to the above storage conditions. Storage at 90 per cent relative humidity was inferior to all in retaining the viability of the seed.

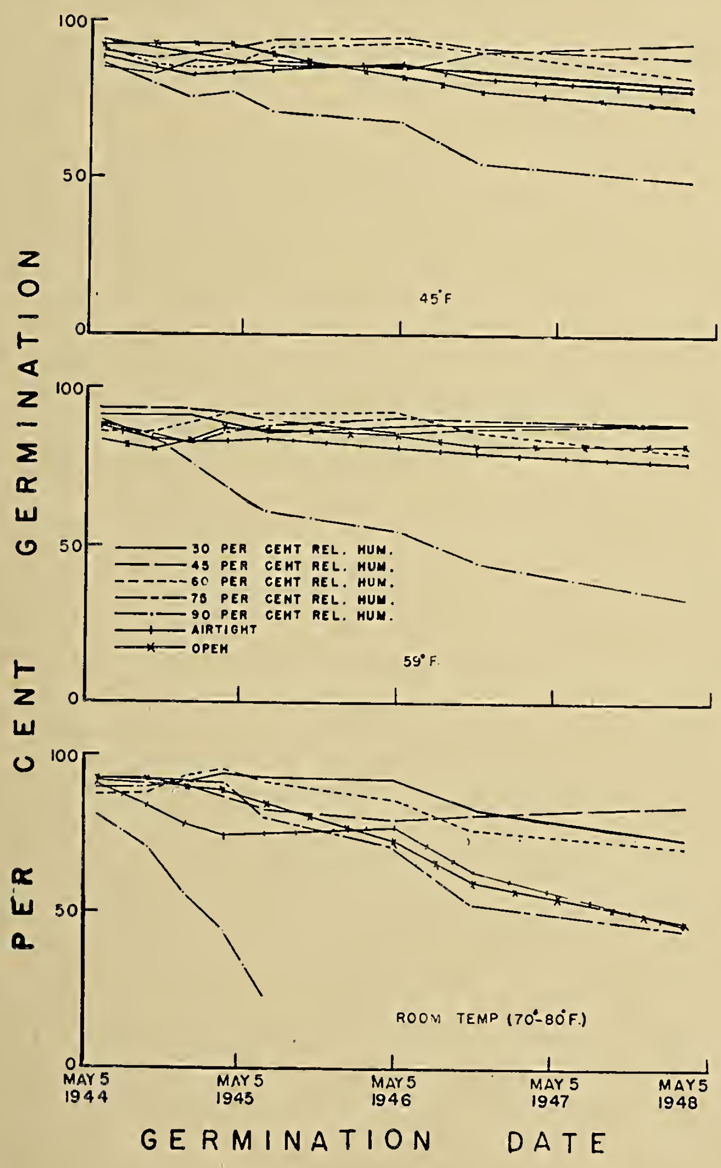

FIG. 3. The effect of temperature and relative humidity on the viability of stored turpentine tree seed.

When the graphs in Figure 3 are superimposed, it is seen that at a relative humidity of 30 per cent, 59° F. was more effective than 45° F. or room temperature in retaining the viability of the seed. At relative humidities of 45, 60, and 75 per cent and in airtight storage, the seed kept in a viable condition longer at 45° and 59° F. than at room temperature. The two lower temperatures were equally effective in this respect. The loss of viability of the seeds stored at a relative humidity of 90 per cent was proportional to the storage temperature; that is, the higher the temperature, the more rapid was the loss in viability. With open storage, 59° F. was slightly superior to 45° F., which in turn was superior to room temperature in maintaining the life of the seed.

From the above considerations, it seemed that an optimum storage medium for the seed of turpentine tree was one in which the relative humidity was maintained at either 30, 45, or 75 per cent at 59° F., or one in which the relative humidity was maintained at either 45 or 75 per cent at 45° F.

Norfolk Island pine seed

The germination behavior of the seed of Norfolk Island pine in storage at various relative humidities and temperatures is presented in Figure 4. At room temperature, no matter what the storage condition, the longevity of the stored seed was very short (Fig. 4). At this temperature, open storage seemed to be slightly superior to the other types of storage. At 59° F., the lower relative humidities, especially the 45 per cent, preserved the viability of the seed better than the higher humidities. At 45° F., the most striking occurrence was the position of the 30 per cent relative humidity curve. As a storage medium, this humidity was inferior to all the other storage media. The 60 per cent relative humidity at 45° F. seemed about the optimum storage medium, with the 75 per cent humidity a close second. In general, up to a relative humidity of 75 per cent, the higher the humidity, the better the seed kept in a viable state. At a relative humidity of 90 per cent, the seed did not keep any better than that in open storage. Though inferior to the 60 and 75 per cent relative humidities, the airtight storage was superior to the open storage for maintaining the longevity of the seed at 45° F.

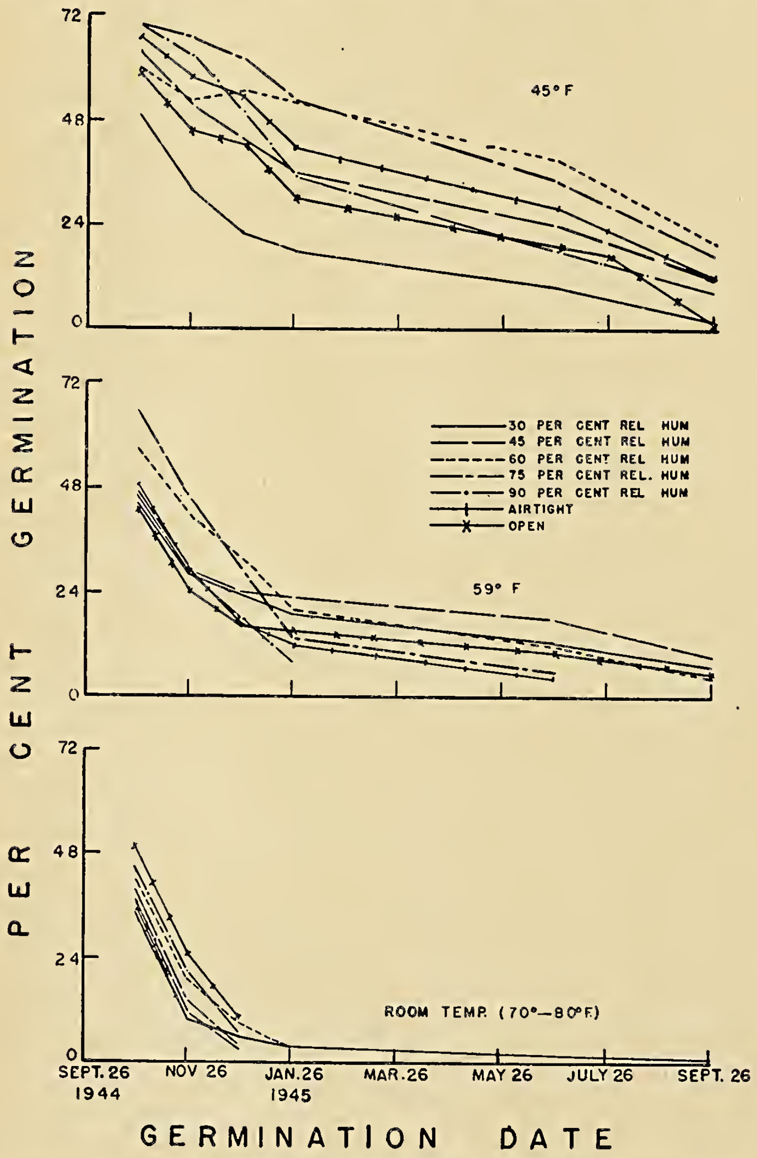

FIG. 4. The effect of temperature and relative humidity on the viability of stored Norfolk Island pine seed.

When the graphs in Figure 4 are superimposed, it will be seen that, in general, the germination curves of the seeds stored at 45° F. lie above those of the seeds stored at 59° F. and that the latter curves in turn lie above those of the seeds stored at room temperature. Thus it seems that regardless of the storage medium, the lower the temperature, the longer was the seed kept in a viable condition.

From the above considerations, it seemed that storing the seed of Norfolk Island pine at a relative humidity of 60 per cent at 45° F. extended the germinative life of this seed.

Mamani seed

In Figure 5 is presented graphically the germination behavior of the seed of mamani in storage under various conditions. Unfortunately, shortage of seed supply necessitated the termination of some germination tests before the experiment was concluded. As a result, in these instances, accurate comparisons between the different storage media could not be made. Nevertheless, it seems that in open storage this seed remained viable for an extended period of time even at room temperature. At the lower temperatures of 45° and 59° F., open storage was probably superior to the other storage media.

When all the storage media are taken into consideration, it seems that as a whole the lower temperatures of 45° and 59° F. were slightly superior to room temperature in maintaining the longevity of mamani seed (Fig. 5). These low temperatures were equally effective in prolonging the viability of this seed.

From the above considerations, it followed

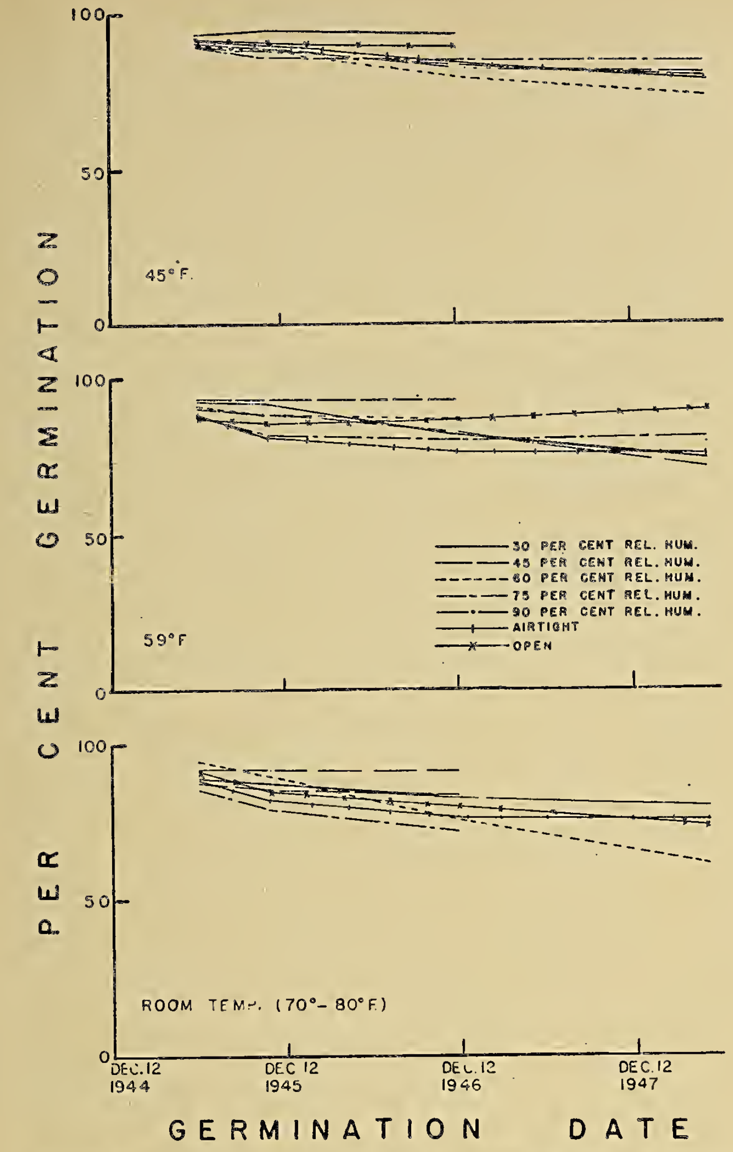

FIG. 5. The effect of temperature and relative humidity on the viability of stored mamani seed.

that storage of mamani seed in the open at temperatures of 59° or 45° F. seemed to be the optimum storage condition for maintaining the viability of this seed over an extended period of time.

Monterey cypress seed

The germination behavior of Monterey cypress seed in storage under various conditions is presented in Figure 6. At room temperature, the lowest and the highest relative humidities were the least effective in maintaining the viability of this seed. The 45 and 75 per cent relative humidities were more effective. The 60 per cent relative humidity was the most effective storage medium at room temperature. The airtight storage and open storage were inferior to only the 60 per cent relative humidity. At 59° F., the 30 per cent relative humidity was the least effective storage medium, and the 60 per cent relative humidity was the most effective. The position of the germination curves of the 45, 75, and 90 per cent relative humidities was approximately midway between the curves of these two humidities (Fig. 6). The curve of the airtight storage approached that of the 30 per cent relative humidity, and the curve of the open storage approached that of the 60 per cent relative humidity. At 45° F., the most effective medium was the open storage, and the least effective was the airtight storage. The 30, 45, and 60 per cent relative humidities were equally less effective than the open storage. The highest relative humidities, 75 and 90 per cent, were somewhat superior to the airtight storage toward the latter part of the storage period in maintaining the viability of the seed at 45° F.

When the graphs in Figure 6 are superimposed, it appears that at relative humidities of

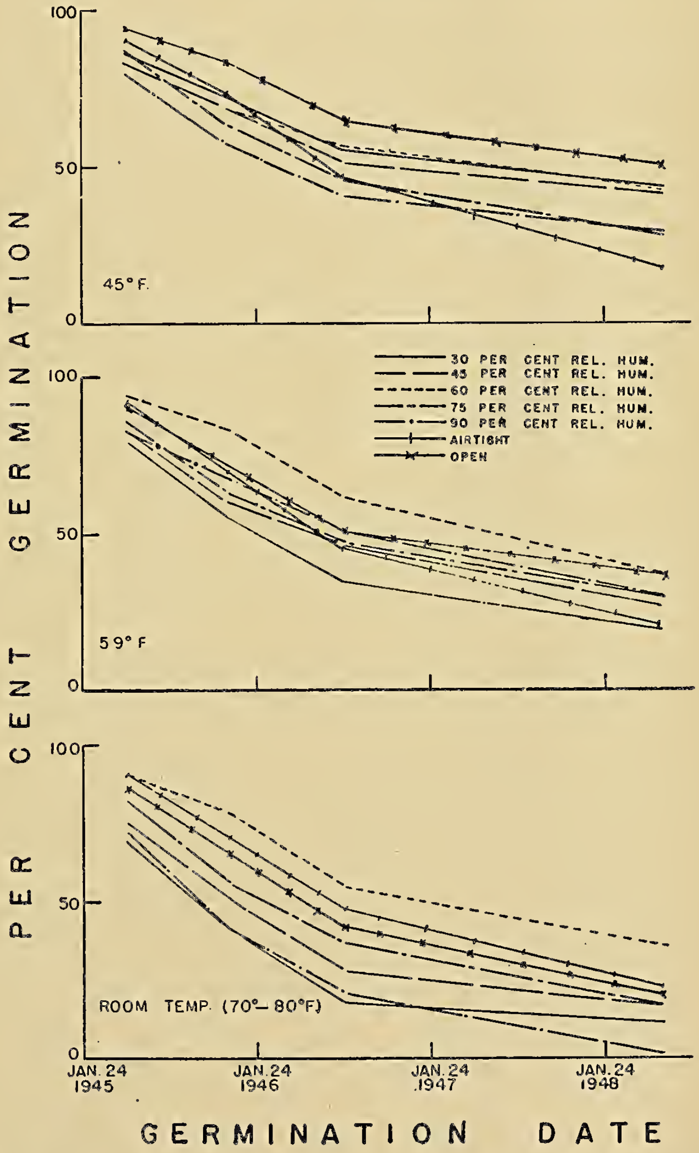

FIG. 6. The effect of temperature and relative humidity on the viability of stored Monterey cypress seed.

30 and 45 per cent and in open storage, the lower the temperature the longer the seed remains viable. At a relative humidity of 60 per cent and with airtight storage, the three storage temperatures were equally effective in preserving the viability of the seed. At 75 per cent relative humidity, temperatures of 45° and 59° F. were equally more effective than room temperature. At 90 per cent relative humidity, 59° F. was more effective than 45° F., which in turn was more effective than room temperature.

From the above considerations, it seemed that storing the seed of Monterey cypress in the open at 45° F. prolonged the life span of this seed better than storing under any other condition.

Indian sandalwood seed

Because of the limited supply of Indian sandalwood seed, only a few seeds were used in the germination tests (Table 1). Nevertheless, the results obtained seemed reliable.

The germination status of this seed at various periods of storage under varying conditions is depicted graphically in Figure 7, which indicates that at room temperature, the low relative humidities of 30, 45, and 60 per cent seemed to be the optimum storage media. The high relative humidities of 75 and 90 per cent were the least effective in preserving the life of the seed. The airtight storage and open storage were intermediate between these humidity groups in this respect. At 59° F., the lower the relative humidity the longer the seed kept viable. The airtight storage and open storage were less effective than the 45 per cent relative humidity but more effective than the 60 per cent humidity at this temperature. In general, the lower relative humidities were more effective than the higher humidities in maintaining the viability of the seed at 45° F. The optimum relative humidity was probably 45 per cent. Seeds stored in airtight containers and in the open retained their viability approximately to the same degree as those stored at the relative humidity of 60 per cent at this temperature.

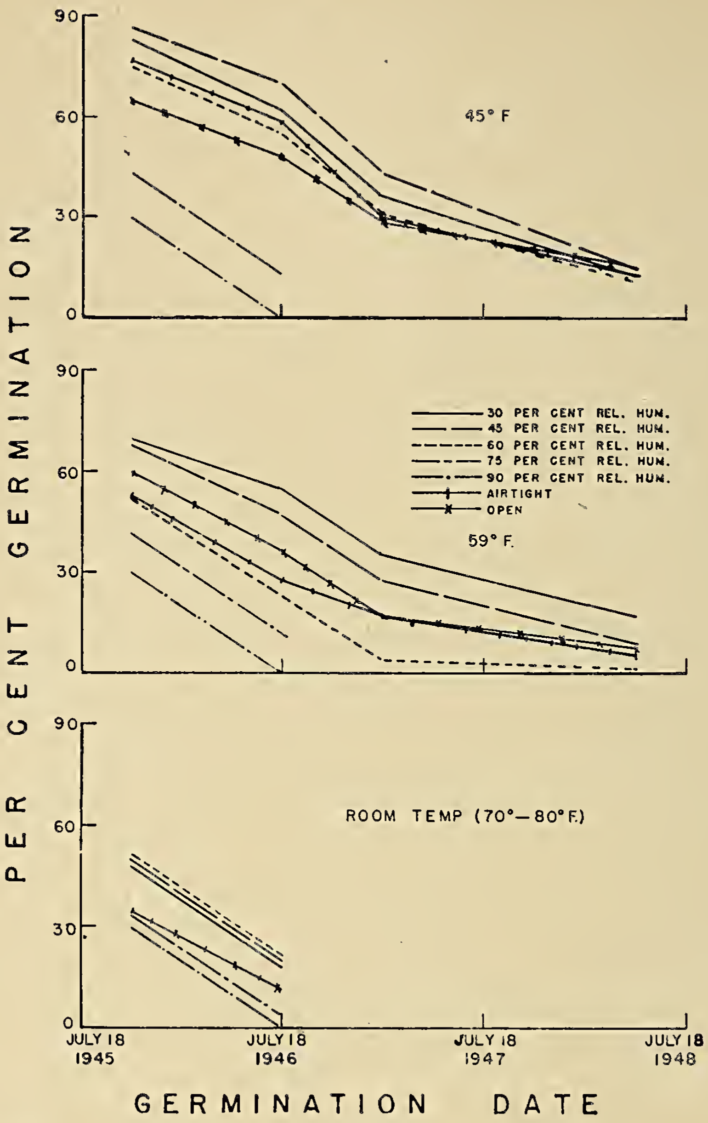

FIG. 7. The effect of temperature and relative humidity on the viability of stored Indian sandalwood seed.

When the germination curves of the seeds stored at the same humidities at each temperature are compared with each other, it will be seen that at relative humidities of 30, 45, and 60 per cent, 45° F. was more effective than 59° F., which in turn was more effective than room temperature in maintaining the viability of the seed (Fig. 7). At a relative humidity of 75 per cent, 45° and 59° F. were equally more effective than room temperature. At a relative humidity of 90 per cent, the three temperatures were equal in effectiveness. In airtight storage and in open storage, the lower the temperature the longer the seed remained viable.

From the above considerations, it can be stated that the optimum storage condition for Indian sandalwood seed was one in which the temperature and the relative humidity were maintained at 45° F. and 45 per cent, respectively.

DISCUSSION

If the longevity of the seeds of all species under all conditions of storage is considered as a whole, it will be seen that these seeds fall in one of the following groups: long-lived seed, medium-lived seed, and short-lived seed. The seed of mamani falls in the first group. In the second category fall the seeds of paper bark, turpentine tree, and brush box. The seeds of Monterey cypress, Indian sandalwood, and Norfolk Island pine are short-lived.

The retention of viability by the seed of mamani was probably due to the impervious nature of its seedcoat, which interfered with the uptake of moisture and with respiration. It will be remembered that this seed required scarification for germination. Generally speaking, regardless of the condition of storage, this seed maintained its viability for 3½ years (Fig. 5).

In general, among the medium-lived seeds, the seeds of paper bark and turpentine tree maintained their viability in storage for 4 years, slightly better than the seed of brush box (Figs. 1, 2, and 3).

In general, among the short-lived seeds, the seed of Monterey cypress retained its viability better than that of Indian sandalwood, which in turn maintained its viability better than the seed of Norfolk Island pine (Figs. 4, 6, and 7).

Although different species reacted somewhat differently toward the various storage conditions, in general, the lower relative humidities were more conducive than the higher humidities to the preservation of viability. There were, however, two species (Monterey cypress and Norfolk Island pine) which were exceptions to this statement. Monterey cypress seed stored at 30 per cent relative humidity at room temperature did not maintain its viability any better than that stored at 90 per cent relative humidity at this temperature (Fig. 6). The 30 per cent relative humidity at 59° F. was the least effective storage medium for this seed. At a temperature of 45° F., the 30 per cent relative humidity was also the least effective storage medium for the seed of Norfolk Island pine (Fig. 4).

SUMMARY

The effects of temperature and relative humidity on longevity of seeds of seven forest tree species in storage for several years were studied.

Although seeds of different species reacted somewhat differently toward the various storage conditions, in general it can be stated that the longevity of these seeds can be maintained in Hawaii if the temperature of the storage medium is maintained at a lower level than that of the prevailing atmosphere (70°–80° F.), if the relative humidity is maintained at a lower level than that of the prevailing atmosphere (66–71 per cent), or if both the temperature and relative humidity are maintained at lower levels than those of the air.

The following were found to be the optimum media for the storage of seeds of the individual species in Hawaii:

Paper bark—Relative humidity of 45 per cent at room temperature or open storage at 59° F.

Brush box—Relative humidity of 45 per cent at room temperature or airtight storage at 45° F.

Turpentine tree—Relative humidity of 45 per cent at 59° F.

Norfolk Island pine—Relative humidity of 60 per cent at 45° F.

Mamani—Open storage at 59° F.

Monterey cypress—Open storage at 45° F.

Indian sandalwood—Relative humidity of 45 per cent at 45° F.

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Pacific Symphytognathid Spiders

B. J. MARPLES[1]

THE FAMILY SYMPHYTOGNATHIDAE was erected by Hickman (1931) for a minute spider, *Symphytognatha globosa*, from Tasmania. The most characteristic feature is the absence of lung-books, the anterior spiracles leading into tracheal tubes which supply the cephalothorax as well as the abdomen, while the posterior spiracles are absent. In *S. globosa* the female has no palps. Fage (1937) and Gertsch (1941) have transferred several other genera into this family, or described new ones. In some of these only four eyes are present instead of the usual six, and the female palps may be merely reduced in size instead of absent.

Some of the specimens described in the present paper were collected in 1946 in Upolu, Western Samoa, during a visit devoted to the collection of arachnids; a few hours of collecting in Suva, Fiji, on the return journey, yielded specimens of a closely related but quite distinct species. Because this is a peculiar and interesting family which has not previously been recorded from the Pacific islands, it seemed desirable to deal with both species together. The main Samoan collection is being dealt with as a whole.

In the following descriptions the leg index, given below the leg formula, is the length of the leg divided by the length of the carapace. The tibial index is the breadth of the proximal end of the patella expressed as a percentage of the combined lengths of the tibia and patella.

Patu gen. nov.

Six eyes. Chelicerae fused for about half of their length. Ventral end of the retromargin of the cheliceral groove with a large bifurcated process. Palp of female absent. Three claws, ventral one large. Abdomen pear-shaped with ventral spinnerets. Close to genus *Symphytognatha*, but different in web and coccoon and in a number of minor structural characters. Genotype: *Patu vitiensis*.

Patu vitiensis n. sp.

Three ♀, 1♂, 1 immature♂. From tree trunks, Suva, Fiji.

FEMALE: Length 1.20 mm. Carapace, sternum, and mouth parts brown, legs lighter. Abdomen mottled greyish-brown above, darkening towards the posterior end. Ventral surface behind the spinnerets very much lighter, almost cream-coloured.

Carapace: Length 0.37 mm., breadth 0.32 mm. Highest near the eyes, which are near the anterior margin.

Eyes: Six, all pale. Posterior row recurved. Lateral eyes touching. PME separated from one another by one quarter of their diameter and from the PLE by rather more than their diameter. Ratio of eyes PLE:ALE:PME = 71:68:60. Eye group breadth 0.23 mm.

Chelicerae: No boss or stridulating organ. Apparently fused for rather less than half of their length. Fang stout with relatively large serrations, and longer than the groove. The ventral retromargin of the groove with a stout process bifurcated into two blunt teeth.

Maxillae: Converging but not meeting above the lip.

Lip: Broader than long.

Sternum: Length 0.23 mm., breadth 0.22 mm. Convex.

Palp: No vestige visible even in cleared

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specimens, though a stout hair arises in the same spot.

Legs:	1	4	2	3
	2.9	2.8	2.6	2.1

	FEMUR	PATELLA AND TIBIA	METATARSUS	TARSUS	TOTAL
I	0.35	0.37	0.21	0.19	1.12
II	0.31	0.35	0.14	0.19	0.99
III	0.28	0.24	0.08	0.17	0.77
IV	0.35	0.35	0.14	0.21	1.05

Tibial Index I......13.1 Tibial Index IV......13.6

Three claws, the median one being long, sharp and downcurved, and larger than the paired ones. The median claw on legs I and II has one tooth; all the other claws are without pectinations. A few serrated bristles on the feet. No spines, but a large erect bristle towards the distal end of each patella, two smaller ones on tibia I, and one on tibia II. One trichobothrium on metatarsi I and II, three on tibiae I and II, two on III, and four on tibia IV.

Abdomen: Length 0.88 mm., breadth 0.56 mm. Pear-shaped with a rounded posterior end. The six spinnerets are ventrally placed, the anterior being the largest. Anal tubercle widened transversely. No colulus. Epigyne in the form of a transverse furrow overhung from in front by a rounded lip. Internal structure seen in a cleared specimen as in the figure. Pair of striated structures on the pedicel as in *S. globosa*, where they were interpreted by Hickman (1931) as lyriform organs and by Petrunkevitch (1933) as stridulating organs.

MALE: Length 0.76 mm. Carapace, sternum, and mouth parts brown, legs light brown. Abdomen light yellowish-brown, posterior end black. Anterior part of the sides slightly darker, there being a very faint suggestion of a dorsal band joining these areas. More well marked are two triangular dark areas anterior to the posterior black cap. Together they form a procurved crescentic dark marking, interrupted in the mid-dorsal line by the yellowish-brown ground colour of the abdomen.

Carapace: Length 0.30 mm., breadth 0.31 mm. Sloping up steeply to the conspicuous row of eyes. Anterior to the eyes is a sinuous ridge, concave above the chelicerae and curving forward in the middle line. This has the appearance of being the anterior edge of the

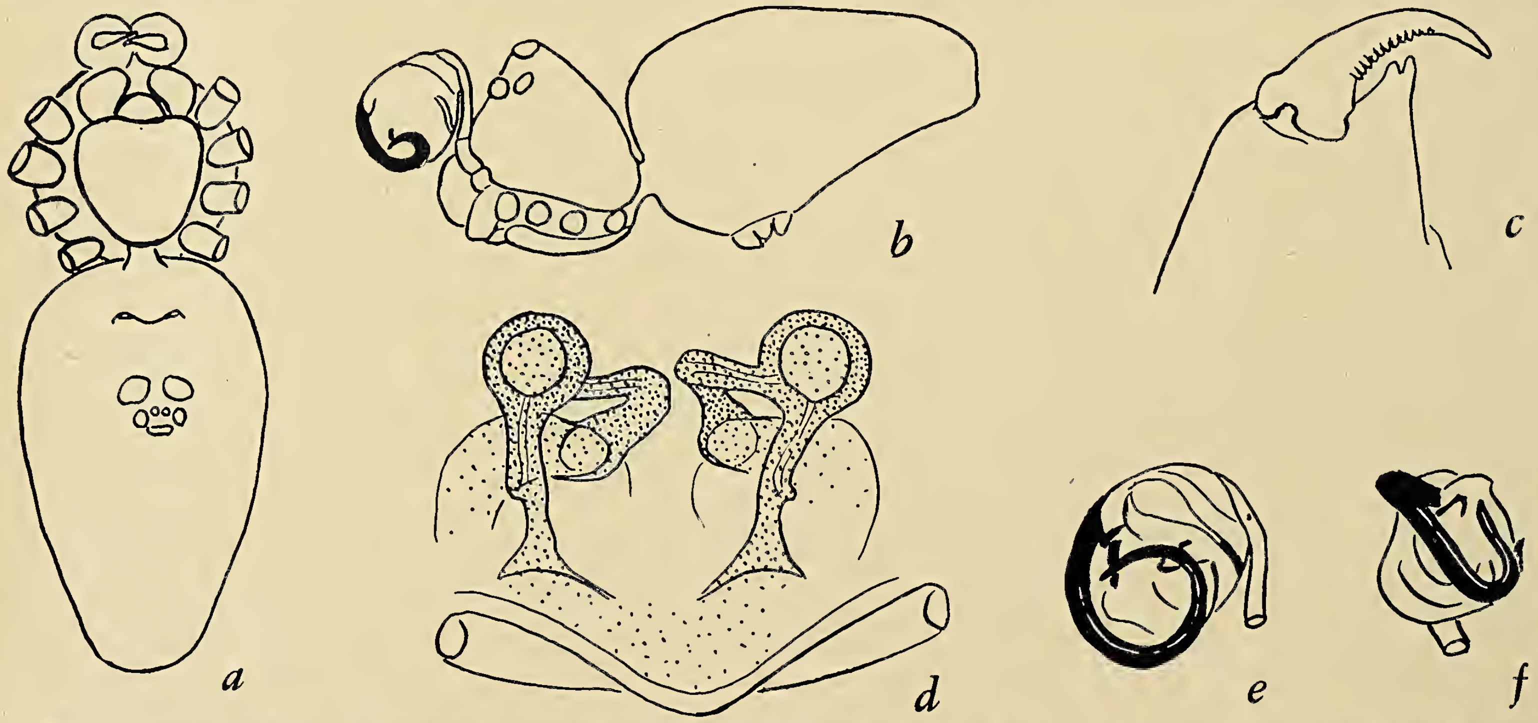

FIG. 1. *Patu vitiensis: a*, female, ventral view; *b*, male, left side; *c*, female chelicera, dorso-retrolateral view; *d*, female apparatus as seen in a cleared skin; *e*, male palp, retrolateral view; *f*, male palp, ventral view.

carapace, but below it is a more or less vertical clypeus. The details are very difficult to make out, owing to the small size.

Eyes: Six, all pale. Posterior row slightly recurved. The PME are separated from one another by about half their diameter and from the PLE by almost their diameter. The lateral eyes are touching. Ratio of eyes, PLE:PME:ALE = 75:70:51. Breadth of eye group 0.23 mm. The PME are separated from the anterior ridge by about half their diameter and from the anterior edge of the carapace by about two and a half times their diameter.

Chelicerae: Small.

Maxillae and Lip: As in female.

Sternum: length 0.24 mm., breadth 0.19 mm.

Palp: Large and rounded palpal organ, details as in figure.

Legs:	1	2	4	3
	3.8	3.3	2.7	2.4

	FEMUR	PATELLA AND TIBIA	METATARSUS	TARSUS	TOTAL
I	0.31	0.36	0.16	0.23	1.06
II	0.26	0.33	0.14	0.19	0.92
III	0.20	0.23	0.10	0.15	0.68
IV	0.27	0.30	0.11	0.16	0.84
Tibial Index I......11.3		Tibial Index IV......12.5			

One stout spine on the ventral surface of tibia II about one third of its length from the distal end.

Abdomen: Length 0.55 mm., breadth 0.33 mm. Pear-shaped with the narrower posterior end truncated. Spinnerets ventral and close to the petiolus.

Web and Coccoons: The webs were situated on tree trunks and consisted of fine horizontal sheets about 4 centimeters long. The silk was too fine for the arrangement of threads to be made out. No oblique thread was noticed as in the Samoan species, though a bunch of coccoons was hanging some way from the edge. Spiders were seen sitting in the centre instead of with the coccoons; possibly these may have been males while the females were with the coccoons.

Patu samoensis n. sp.

Eight ♀ from minute sheet webs in the irregularities of tree trunks in forest, Apia, Upolu, Western Samoa.

FEMALE: Length 1.63 mm. Carapace, sternum, and mouth parts dark brown. Legs lighter with dark annulations. Abdomen mottled greyish.

Carapace: Length 0.55 mm., breadth 0.43 mm. High and rounded.

Eyes: Six, all pale. Large and conspicuous, posterior row straight. PME separated from one another by less than a quarter of their diameter and from the PLE by less than half their diameter. Lateral eyes touching. Ratio of eyes, PME:PLE:ALE = 78:68:64. Eye groups breadth 0.30 mm. PME twice their diameter from the carapace edge.

Chelicerae: Apparently fused for about half their length and rather cylindrical in anterior view. The fang is longer than the groove and has relatively large serrations. On the ventral retromargin of the groove is a stout process bifurcated into two sharp teeth. The chelicerae do not bulge forward in front of the edge of the carapace when seen in dorsal view.

Maxillae: Converging but not meeting above the lip.

Lip: Broader than long. Junction with sternum distinct.

Sternum: Length 0.30 mm., breadth 0.29 mm. Convex.

Palp: No trace of a palp is to be seen even in a cleared specimen, though three or four hairs arise from the same spot. No palp was visible in the cleared skin of a first instar taken from a coccoon.

Legs:	1	2	4	3
	2.6	2.4	2.4	1.9

	FEMUR	PATELLA AND TIBIA	METATARSUS	TARSUS	TOTAL
I	0.43	0.46	0.26	0.30	1.45
II	0.38	0.43	0.22	0.30	1.33
III	0.31	0.31	0.16	0.22	1.00
IV	0.42	0.42	0.24	0.25	1.33
Tibial Index I......15.8		Tibial Index IV......14.3			

Three claws, the third as large as the dorsal pair and sharply directed downwards. Claws slender and not pectinated, and pectinated bristles not present. No spines, but a large erect bristle at the distal end of each patella, two smaller ones on tibia I and one on tibia II. One trichobothrium on metatarsi I and II, three on tibiae I and II, two on tibia III, and four on tibia IV.

Abdomen: Length 1.16 mm., breadth 0.80 mm. Pear-shaped, projecting behind in a knob-ended process and provided with a pair of similar dorso-lateral processes. The six spinnerets are ventral, the anterior being the largest. No colulus. Anal tubercle large. The epigyne is visible only when the abdomen is removed. There is a transverse fold overhung by a backwardly directed lip whose edge is dark and thickened. The appearance of a cleared specimen is shown in the figure.

In specimens cleared in potash the spiracles could be seen leading into an atrium from which numerous tracheal tubes supplied both the cephalothorax and abdomen. There was a transverse connecting tube between the atria. Sections showed five pairs of tracheal tubes, three large and two small, passing through the pedicel into the cephalothorax.

Web and Coccoon: The webs were spun in the irregularities of a fallen tree trunk. They consisted of a very fine horizontal sheet with very regular meshes. The sheet was an irregular polygon some 6 centimeters long, and an oblique thread extended upwards from the sheet between 1 and 2 centimeters from one end. The threads of the sheet radiated from

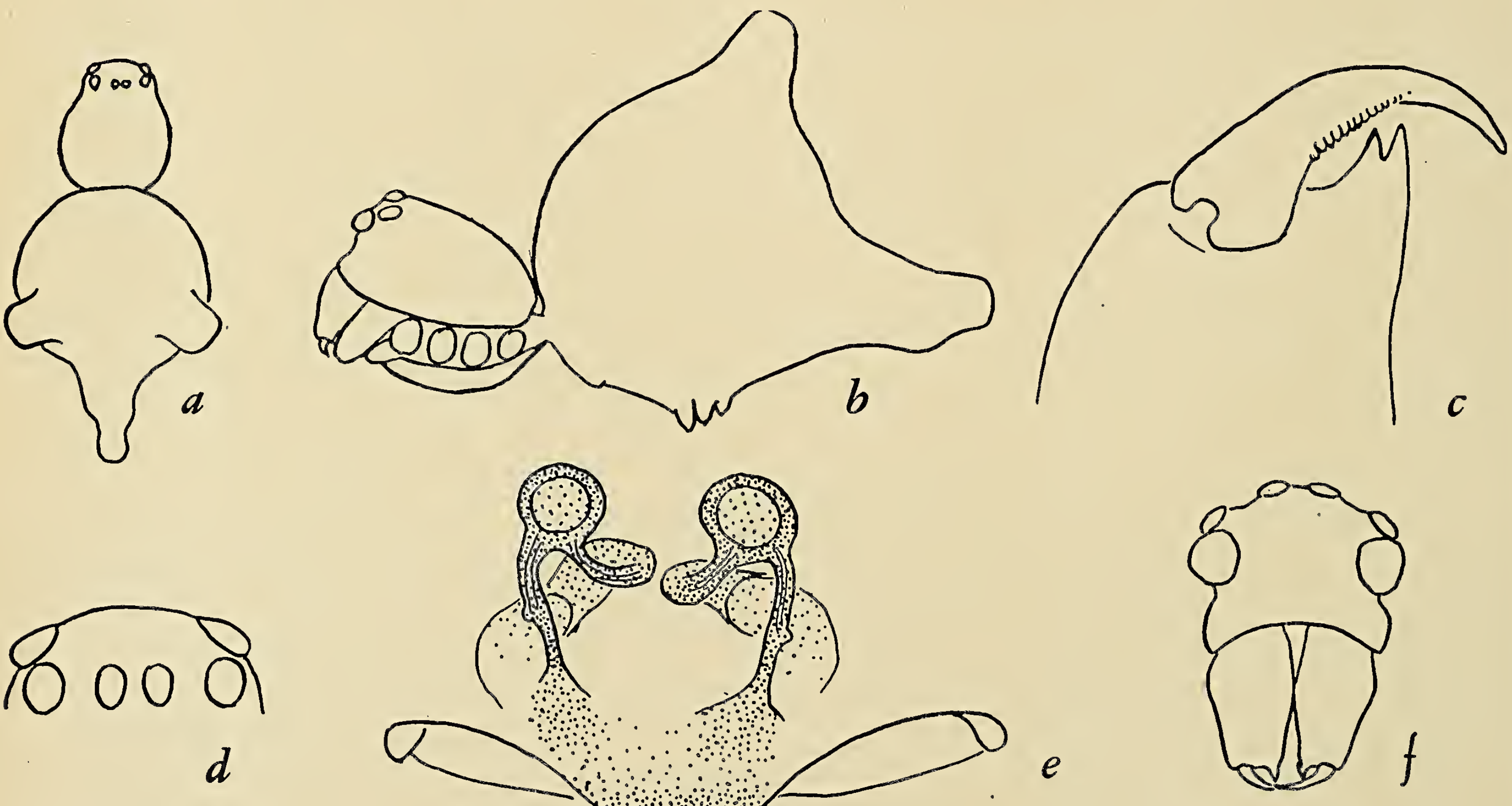

FIG. 2. *Patu samoensis: a*, female, dorsal view; *b*, female, left side; *c*, female chelicera, dorso-retrolateral view; *d*, female, eyes, dorsal view; *e*, female apparatus as seen in a cleared skin; *f*, female, anterior view of carapace and chelicerae.

the point of attachment of the oblique thread, but it was a sheet and not an orb web. The spider rested at this point together with a cluster of coccoons. The coccoons each contained only a single egg about 0.34 mm. in diameter. The coccoon consisted of a sphere some 0.66 mm. in diameter, woven loosely of fine threads so as to be transparent, the whole surface being covered with spirals of thick thread with the loops projecting from the surface. The whole structure was thus 0.83 mm. in diameter. All the silk was white. This is quite unlike the web and coccoon described by Hickman for *S. globosa*. A first instar removed from a coccoon had a globular abdomen with no trace of the projections.

SUMMARY

A new genus of spiders belonging to the family Symphytognathidae is described, with a species from Fiji and another from Samoa. Members of this family have been described from Tasmania, New Caledonia, East Indies, and Central and South America, but apparently not from the Pacific islands. The new genus seems to be close to *Symphytognatha* from Tasmania.

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The Polynesian Species of *Myoporum*[1]

GRADY L. WEBSTER[2]

INTRODUCTION

THIS REVISION was originally begun as an analysis of the notoriously polymorphic species *Myoporum sandwicense* of the Hawaiian Islands. After a considerable amount of work had been done, however, it was found that the forms of *Myoporum* from southern Polynesia were very similar. Because of the closeness of relationship, it seemed both more practical and more worth while to treat all of the Polynesian species together.

In the Hawaiian Islands, *Myoporum sandwicense* is an evergreen shrub or tree which grows mostly in dry forests on leeward slopes from sea level to an altitude of 10,000 feet. Its plasticity in habit is remarkable, as it may become a tree 15 meters high in the dry forests (Rock, 1913: 427) or a creeping, fleshy, prostrate shrub on the beaches and low rocky islets. More rarely it may even invade the rain-forest, as in Waikolu Valley on Molokai.

The Hawaiians used the species, which they called *naio*, for timber in building houses (Brigham, 1908: 83). Apparently it was not cultivated, as it is in Rarotonga (Wilder, 1931: 100), for the perfume of the flowers. There are references (Bennett, 1832: 257; Hooker and Arnott, 1841: 93) concerning the attempts of traders of the 1820's to substitute *naio* wood for sandalwood in the Chinese trade, but neither then nor since has the *naio* attained any real commercial value. Brown (1935: 279) reports that on the island of Rapa (in southern Polynesia) *naio* wood is used for building canoes and houses.

The real value of *Myoporum* to the Hawaiian Islands resides in its role in the formation of a dry forest cover and in the consequent checking of soil erosion. On most of the islands the dry forest region has been partially or completely denuded, with serious consequent erosion. Reforestation work has been carried out chiefly with quick-growing exotic trees such as *Casuarina* and *Eucalyptus*, but the appearance of the resulting vegetation is disappointing from an esthetic point of view. It is to be hoped that eventually the original dry forest trees, such as native species of *Diospyros*, *Acacia*, *Sophora*, and *Myoporum*, will regain a part of their lost dominance. Egler (1947: 425), studying the communities of the dry southeastern section of the Koolau Range on Oahu, predicted that although *Myoporum* was rare at that time it might in the future assume an important place in the *Prosopis* community.

Acknowledgments: Dr. Harold St. John of the University of Hawaii originally suggested this study, made it possible to collect and observe the plants in the field, and has been of great assistance in criticizing and offering suggestions for the manuscript. Mr. Otto Degener loaned his large and important collections for study and discussed with me some of the forms which I was unable to see in the field. Dr. B. C. Tharp readily consented to having the study continue at the University of Texas, and he and Dr. W. Gordon Whaley kindly

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read and criticized the manuscript. I also wish to thank Miss Marie Neal for making available the facilities of the Bishop Museum Herbarium, Miss Mary Lou Jeffrey and Mr. William L. Brudon for drawing the illustrations, and the curators of the herbaria listed below for the loan of specimens:

Bishop Museum, Honolulu (BISH); Boisser Herbarium, Geneva (G-BOIS); Otto Degener, personal herbarium (DEG); Delessert Herbarium, Geneva (G-DEL); Gray Herbarium (GH); Royal Botanic Gardens, Kew (K); New York Botanical Garden (NY); Laboratoire de Phanerogamie, Paris (P); Riksmuseum, Stockholm (S); University of Texas, Austin (T); Naturhistorisches Museum, Vienna (W).

TAXONOMIC POSITION

The genus *Myoporum* consists of about 30 species scattered over a wide area including Mauritius, Australia, New Zealand, New Guinea, China, Japan, Micronesia, and Polynesia. It is characterized by its relatively actinomorphic corolla and its fleshy drupe with usually solitary ovules in the cells. Like other genera in the Myoporaceae, *Myoporum* has axillary flowers, stamens with confluent anther cells, pendent anatropous ovules, and gland-dotted, alternate leaves. The Verbenaceae is probably the most closely related family, but it is well distinguished by its ovules which are not apically attached and by its opposite leaves which lack internal secretory tissue (Solereder, 1899: 711).

The Polynesian species of *Myoporum* belong to section *Pentacoelium* of Gray (1866: 51), which has priority over the more appropriate name *Eumyoporum* of Bentham (1870: 2). Wettstein (1895: 360) distinguished three sections which contained Pacific insular species—*Pentacoelium*, *Polycoelium*, and *Eumyoporum*—but there is no justification for placing these insular species in more than one section. Kraenzlin's sections (1929: 15) are even more poorly founded, so it seems that so far no really satisfactory subdivision of the genus has been made.

The Hawaiian species *M. sandwicense* was apparently first collected by Archibald Menzies on Vancouver's expedition and was at first referred to the New Caledonian *M. tenuifolium* by Hooker and Arnott (1841: 93). It was described as a new species, *Polycoelium sandwicense*, by De Candolle (1847: 705) and was redescribed in the genus *Myoporum* by Asa Gray (1866: 52). No other name was officially proposed for any of the Hawaiian plants until Léveille (1912: 63) published *M. Fauriei* based on a Faurie specimen from the island of Hawaii. Kraenzlin (1929: 21)reduced the species to a variety but appears to have misapplied the name to specimens of var. *sandwicense*.

Hugh Cuming had collected *Myoporum* in the Austral Islands (Tubuai) in 1828, but over a hundred years went by before any new species were described from southern Polynesia. Cheeseman (1903: 291) listed as *Myoporum* sp. a Mangaian plant cultivated on Rarotonga. Wilder (1931: 100) referred the Rarotongan plant to *M. sandwicense*, but Skottsberg (1933: 165) described it as a new species—*M. Wilderi*—and discussed its probable relationships to most of the other insular species. Two years later Brown (1935: 277) published three species from the Austral Islands and Rapa.

Variation in the Hawaiian myoporums has been discussed by Skottsberg in his paper on *M. Wilderi* and by Degener (1930: 261), but neither has published any new names although Degener illustrated a pubescent-leaved form and announced his intention of describing it in his *Flora Hawaiiensis*.

MORPHOLOGICAL CRITERIA

Because of the extreme polymorphism of many Hawaiian populations of *Myoporum* it is difficult to find morphological characters which do not vary as much between individuals as between varieties. An accurate concept of the range of variation—arrived at by observation of a great many specimens—is essential in defining the taxonomic characters of the various groups.

Growth habit, as has been indicated, is so greatly modified by environment that it is probably of no taxonomic significance. The stem is significant only in distinguishing var. *stellatum* from var. *Degeneri*, the former having pubescent branchlets.

There are many leaf shapes but few of them are constant in any one population. Serrate margins are found sporadically among nearly all the Hawaiian varieties and must be used with extreme caution as a taxonomic character. On the other hand, this serrature is constant in the southern Polynesian forms and may be used dependably to separate *M. Stokesii* from *M. rapense*. Conspicuous differences in leaf texture occur among the Hawaiian plants, but in the main these appear to reflect environmental differences. The relative conspicuousness of the nervation depends in turn on leaf texture and is thus obviously unreliable.

The leaves of all the Polynesian species have subepidermal pellucid-punctate tissue, and the distribution and type of these pellucid spots appear to be good specific criteria. *M. Stokesii* and *M. rapense* are difficult to separate from the New Zealand *M. laetum* except for the fact that the glandular spots on the leaves of the latter are far more conspicuous. In *M. laetum* the pellucid spots are visible by reflected light (on the upper leaf surface) and give a distinct "polka dot" effect in transmitted light. The spots of the two Polynesian species are smaller, less conspicuous in transmitted light, and almost invisible in reflected light.

A readily recognizable and often valuable leaf character in Hawaiian *Myoporum* is the presence of pubescence. Unfortunately, while pubescent leaves are constant features of varieties *stellatum* and *Degeneri* they may appear sporadically in populations of other varieties which ordinarily have glabrous leaves. These sporadic occurrences seem often to be a response to wounding caused by grazing animals, although in some cases the lower "sucker" shoots from an uninjured plant may bear pubescent leaves. In fact, even if the leaves on basal or wound shoots are not pubescent, they are often serrate and larger than normal leaves. Furthermore, there is evidence that at least in some groups of *Myoporum sandwicense* the "juvenile" leaves of a young plant are of the abnormal serrate-pubescent type, while those formed later are entire and glabrous. Further investigations on this subject are much to be desired.

The number of flowers in the axillary clusters varies not only between plants but even on the same branch and thus does not appear to be of any great taxonomic value. The same can be said of the flower pedicels, which vary widely, but inconsistently, in length and thickness.

The number and length of the calyx lobes, within certain ranges of variation, are significant, while their shape (on account of its plasticity) is usually less so. The size and shape of the corolla have not been used for distinguishing varieties; although there are readily apparent differences, they are overlapping and inconstant. The amount of pubescence on the corolla throat is usually quite variable and may or may not have significance.

The ovary is generally uniform in shape and constant in size, within any one variety. It is glabrous and has a somewhat expanded, differently colored basal region which seems to be nectariferous. At anthesis the flowers may be noticeably fragrant, although I have personally found the flowers of *M. sandwicense* to be almost odorless. In marked contrast to the Hawaiian species in this regard are *M. Stokesii* and *M. rapense*, whose flowers are credited in collectors' notes as ranging in scent from "strong sweet" to "fetid."

The style furnishes some of the best taxonomic criteria, especially in its length and in the presence or absence of pubescence.

This last character is undoubtedly valuable in delimiting species, although it may occasionally be inconstant (on the islands of Hawaii and Raivavae). The abrupt basal curvature of the style observed in some of the specimens from southern Polynesia is an inconstant character and its importance is hard to assess on the basis of the small amount of material studied.

The number of stamens is one of the classical key characters for separating *M. sandwicense* from the other Polynesian species, but this distinction breaks down when a large number of Hawaiian specimens is examined. The length and height of insertion of the stamens were found to be quite inconstant, and the degree of divergence of the anther cells is dependent on age and is of no taxonomic value at all.

The drupes of most of the Hawaiian varieties differ from the other Polynesian species in having a greenish-white exocarp. Some plants on the island of Hawaii (var. *Fauriei*), however, may have either whitish, pink, or purplish drupes. The drupes of *M. Stokesii* and *M. rapense* are pink or red and brick-red or purplish-red, respectively, while those of *M. laetum* are said to be purple. Judging from the variability of color in *M. sandwicense* var. *Fauriei*, however, it would be unwise to consider differences in shade of color as especially meaningful. The presence of color in the drupes of var. *Fauriei* and its absence in the other Hawaiian varieties do seem to be significant, however.

The bony endocarp is usually subglobose or top-shaped and often ridged at the top or along the sides. Its shape, although extremely variable, is a distinguishing character in some varieties and species. The number of cells in the drupe is inconstant, but a knowledge of the range of variation will assist in placing a specimen in the proper category. Counting the number of cells is not always easy as some of the abortive ones may be quite small. There is often a considerable degree of sterility, for many drupes will be found to contain only one or two cells with well-developed seeds.

TAXONOMIC CATEGORIES

The *species* is here considered to be a population whose individuals have in common an ensemble of fundamental morphological characters different from that present in other species. It is reasonable to suppose that this morphological distinctiveness is due to various types of barriers (such as geographical, physiological, and genetical) which prevent a free genetic exchange with other species.

The categories *subspecies* and *variety*, as here used, apply to groups which occupy a discrete region within the total area of the species and which are characterized by a lack of sharp morphological distinctness from other groups within the species. A subspecies differs from a variety in its greater morphological differentiation, but does not necessarily occupy a greater area. Both are considered to lack genetic isolation—that is, varieties of the same species would be expected to interbreed freely when brought together—and no doubt often owe their existence to geographical barriers.

In recent years there has been considerable discussion among taxonomists as to whether the geographically delimited groups within a species should be given the rank of subspecies or of variety. However, in this work it has seemed better to use both categories in order better to accommodate the great sub-specific range of differentiation.

The *form*, in the present intrepretation, is a group of plants which occur within a variety and differ by very minor or inconstant characters; they may or may not be geographically localized. Specimens may also be referred to forms when they are inadequate to give an accurate concept of the population. Inasmuch as the forms listed in this study are not conveniently separated morphologically and to some extent are designations based on incomplete knowledge, it seems unwise to dignify them with Latin names. For convenience they are listed by number, each under the island where it occurs.

DISTRIBUTION

So far species of *Myoporum* have not been discovered on any of the islands occurring in the 3,000-mile expanse of sea between Hawaii and the Austral Islands. It is not surprising that they are missing from low coral atolls such as Palmyra and Fanning, but their absence from the Society Islands, the Marquesas, and Makatea is unexpected, as is their absence from other large Pacific islands such as Samoa and Fiji.

The disjunct distribution of *M. sandwicense*—with two subspecies in the Hawaiian Islands and one in the Cook Islands (Mangaia)—is not unique, however. For instance, *Isachne distichophylla* has been found only on Rarotonga and in the Hawaiian Islands. *Hedyotis* section *Bikkiocarpa* has two species, one from West Maui and one from Rapa (see Fosberg, 1943: 25). The genus *Phyllostegia* has 23 species in the Hawaiian Islands and one in Tahiti. Our present state of knowledge is insufficient to explain these facts of distribution. However, the theory of Zimmerman (1948: 49–52) that high volcanic islands, now reduced to reefs or atolls by erosion, once existed as stepping-stones in the mid-Pacific indicates how these cases of bicentric distribution might have arisen.

At the time of Captain Cook's visit *Myoporum* undoubtedly existed on all seven of the main Hawaiian Islands. It is now absent from the denuded island of Kahoolawe, but Forbes (1913: 86) learned from old visitors to the island that the *naio* had been seen there before the dry forest was wiped out. The relative abundance of the species at those localities where it still persists has no doubt undergone great changes. In some areas, as at Kaena Point on Oahu and the Puuwaawaa district of Hawaii, it may be as common as it was before the dry forests were disturbed; on the other hand it is rare or absent from areas such as the Lualualei region on Oahu, western Molokai, and the Kohala peninsula of Hawaii, where probably it was once very abundant.

In the Austral Islands the destruction of the native forests has been so complete that a clear picture of the distribution of *Myoporum* there may never be obtained. St. John tells me that he made a special effort to collect *Myoporum* on these islands during the Mangarevan Expedition of 1934 and that few plants of the genus could have been overlooked in the vestiges of the native forest. Judging from his findings, *M. rapense* var. *Skottsbergii* and the form described by Brown as *M. rimatarense* may well be extinct.

On the basis of our present knowledge, however, it seems significant that *M. rapense* is found on the three lower islands of the Austral group and that its derivative *M. Stokesii* is restricted to Raivavae.

One of the chief difficulties in understanding the distributional pattern of Polynesian *Myoporum* is that the means of long-range dispersal of the genus are still a matter of conjecture. It does not appear likely that the fruits are spread by ocean currents, since my own observations show that they will float for no more than a few days. Dispersal by birds is a possibility, since some endemic Hawaiian birds were known to have eaten the seeds; but there is no evidence that any migratory birds are fond of the fruits. It must be admitted that the dispersal mechanism of *Myoporum* still remains unknown, and that the accidental transport by hurricanes is as likely a possibility as any.

RELATIONSHIPS OF THE SPECIES

At present, and in spite of a fairly recent monograph (Kraenzlin, 1929), the genus *Myoporum* is in great need of critical revision. The seat of the greatest systematic difficulty is the complex of chiefly insular species which includes the three Polynesian species. Almost nowhere within this insular complex are the species well defined, and it is very difficult to find morphological characters sufficiently constant to distinguish them.

Because of its great range of morphological variation, *M. sandwicense* poses a particularly difficult problem in species definition. In its most typical form the species is well characterized by its flowers with five stamens and a glabrous style, and by its whitish-colored drupes with five or more cells. To some extent, however, every one of these characters proves to be inconstant when the complete range of variation of the species is ascertained. The other Polynesian species typically differ in having flowers with four stamens and pubescent styles as well as reddish-tinted drupes with fewer cells, but most of these characters are inconstant. However, *M. sandwicense* not only approaches the other Polynesian species very closely, but also is hard to separate from *M. tenuifolium*, a species lying to the west and southwest in Micronesia and Melanesia. This latter species is characterized by the small size of its flowers and fruits; but there are forms of *M. sandwicense* whose reproductive organs are of about the same dimensions. Of course, in all these cases species distinctions can be maintained by using rather complicated combinations of characters; for instance, *M. tenuifolium* can be separated from *M. sandwicense* by the fact that the forms of the latter which have small flowers and fruit do not have pink-tinted drupes. Such contrived species differences are admittedly unsatisfactory, but they will have to serve for the present. The temptation to combine various of the insular species should be resisted until the entire group is surveyed, because only then will it be possible to define the exact limits of *M. sandwicense* and its nearest congeners.

Because the classification of the insular myoporums is still in a very imperfect state, one hesitates to speculate as to the phylogeny of the Polynesian groups. However, the following observations on the possible relationships of the Hawaiian groups seem worthy of statement.

It is pretty clear that the group of *M. sandwicense* showing the greatest resemblance to the Austral Island species is ssp. *Wilderi*, although it is not possible to say whether or not the latter originated directly from or coordinately with the Austral Island species. Among the groups of *M. sandwicense* from the Hawaiian Islands proper, var. *Fauriei* shows the greatest resemblance to ssp. *Wilderi*. Because var. *Fauriei* is restricted to the island of Hawaii, it seems likely that this island was the point of immigration of *Myoporum*. Degener (1930: 266), on the basis of the occurrence of pubescent, serrate leaves on certain wounded plants from Molokai, has suggested that the direct ancestor of the Hawaiian forms had leaves of this type. However, this phenomenon does not seem to be a case of a reversion to an immediate ancestral type, but rather the expression of a potentiality which is widespread, inasmuch as independent occurrences of pubescent leaves are known from other Hawaiian islands as well as from Australia, New Zealand, and New Caledonia.

It seems evident that var. *sandwicense*, the most widely distributed of the Hawaiian groups, is derived from var. *Fauriei*, while it in turn has given rise to varieties *lanaiense*, *Degeneri*, and *stellatum*. The origin of ssp. *St.-Johnii* is more obscure. It could have come directly from the adjacent population of var. *Fauriei*, but the rather great morphological differences between the two entities make this rather questionable. The history of *Myoporum* on the island of Hawaii is made even more mysterious by the fact that var. *sandwicense* is absent from this island, even though it is presumed to have originated there. This suggests that the original population of var. *sandwicense* on Hawaii has become gradually modified into the group now known as ssp. *St.-Johnii*. This suggestion is of course hypothetical, but it would explain the curious anomaly of the absence of var. *sandwicense* from its presumed place of origin, as well as the occurrence on Hawaii of forms of ssp. *St.-Johnii* very similar to var. *sandwicense.*

On each island of the Hawaiian group independent modifications, some of which are superficially similar and have resulted in a sort of parallel evolution, have arisen in the populations. This curious phenomenon, which is characteristic of populations on some other Pacific islands as well, has been remarked on by Degener (1930: 266), who realized the independent origins of the hairy-leaved and "peach-leaved" forms on the various Hawaiian islands. Even more perplexing from the taxonomic point of view is the occurrence of reversions of characters. Thus, in tracing the character of style pubescence in the Polynesian species, we find that it is present in *M. rapense*, beginning to disappear in *M. Stokesii*, absent in ssp. *Wilderi*, but reappearing in ssp. *St.-Johnii.* Naturally this sort of behavior of morphological characters introduces great hazards in classifying and interpreting the phylogeny of the Polynesian species.

It is interesting that there seems to be little evidence of inter-varietal hybridization in the Hawaiian Islands. No indubitably hybrid specimens have been seen except possibly from the island of Hawaii, and here additional field work will be necessary to establish the actual hybrid nature of such specimens. The conclusion seems inevitable that evolution in Hawaiian *Myoporum* has been most strongly conditioned by geographical isolation, while inter-varietal hybridization has not played an important part. The fast rate of differentiation and slow dispersal rate of the populations have been acting together to produce an intense micro-evolution. The taxonomic difficulty of characterizing *M. sandwicense* is a reflection of the rapidity and recentness of this process. Within this one species can be found groups at all stages of differentiation—from individual variants to populations of almost specific distinctness.

Owing to the ruination of much of the flora of the Austral Islands, our knowledge of the groups there is rather incomplete. Nevertheless, it is clear that *M. rapense* is very closely related to *M. laetum* of New Zealand and is no doubt derived from it or a similar type. On Rapa and Tubuai it has changed little from the original immigrant, but on Raivavae it has given rise to and been almost supplanted by the polymorphic *M. Stokesii*, which itself is undergoing incipient speciation in the manner of *M. sandwicense.*

SYSTEMATIC TREATMENT

It is not pretended that the taxonomic arrangement which follows is definitive. Further collecting on some of the Hawaiian Islands may necessitate a reappraisal of some of the unnamed forms listed herein and should result in the discovery of additional forms and perhaps even new varieties. Adequate understanding of a highly polymorphic genus such as *Myoporum* requires accurate field observations, and careful notes by collectors concerning flower color and scent, fruit color, and leaf variation will be of great assistance in future studies.

MYOPORUM Soland. ex Forst. f., Prodr. 44. 1786.

Generic synonyms pertinent to the Polynesian species are:

Pentacoelium Sieb. & Zucc., Abh. Akad. Muench. 4(3): 151. 1846.

Polycoelium A. DC., Prodr. 11: 705. 1847.

Prinastrum Nutt. ex Gray, Am. Acad. Sci. 6: 53. 1866 (as synonym).

Low or erect shrubs, rarely tall trees. Leaves alternate (rarely opposite), sessile or with a winged petiole, linear to lanceolate or elliptic, entire or serrate, glabrous or rarely pubescent, often viscid when young. Flowers axillary, solitary or clustered, ebracteolate-pedicellate; calyx usually deeply 5-lobed, green and herbaceous, gland-dotted. Corolla usually 5-lobed, imbricate in the bud, subactinomorphic, campanulate to funnelform, glabrous without, glabrous or pubescent within, usually glandular-punctate. Stamens usually 4, rarely more, alternate with the corolla lobes; filaments subulate or terete, glabrous or pubescent, adnate to the corolla; anther sacs confluent. Ovary of various shapes, often conic-cylindric, usually 2–5-celled (rarely the cells more numerous); style simple, usually as long as or longer than the ovary; stigma convex, entire or obscurely 2–5-grooved (rarely bifid); ovules solitary or rarely paired in each cell of the ovary, anatropous, pendent from the apex of the cell. Fruit a fleshy drupe; endocarp bony, usually more or less subglobose but sometimes depressed or laterally compressed; seeds spindle-shaped, with scanty endosperm, the radicle superior.

TYPE SPECIES: *Myoporum laetum* Forst. f., here chosen as lectotype for the genus. It should be noted that Forster attributed the authorship of the genus *Myoporum* to Solander alone, and not to Banks and Solander, as subsequent writers have incorrectly done.

Section PENTACOELIUM (Sieb. & Zucc.) A. Gray, Proc. Am. Acad. Sci. 6: 51–52. 1866.

Pentacoelium Sieb. & Zucc., Abh. Akad. Muench. 4(3): 151. 1846 (as a genus).

Polycoelium (A. DC.) A. Gray, *op. cit.* (as a section).

Eumyoporum Bentham, Flora Australiensis 5: 2. 1870 (as a section).

Insularia Kraenzlin, Fedde Repert. Sp. Nov., Beih. 54: 15–16. 1929 (as a section).

Ovary mostly 2–4-celled; ovule, one in each cell. Drupe mostly subglobose, not strongly laterally compressed.

KEY TO THE POLYNESIAN SPECIES

This key is intended for use in determining specimens in flower and fruit. Sterile twigs from the base of a plant or from a wounded branch may sometimes have serrate and/or densely pubescent leaves very unlike the normal ones. Specimens of this unusual type should be accompanied by normal flowering branches if the correct determination is to be made.

A. Style glabrous, or if hirsutulous then 2–3.5 mm. long and fruit not red-tinged... 1. *M. sandwicense*

B. Style glabrous.

C. Stamens usually 5 (less commonly 4 or 6); corolla glabrous or pubescent; leaves various, not elliptic-spatulate and abruptly acute............................... 2. ssp. *sandwicense*

D. Leaves glabrous.

E. Endocarp strongly depressed, not or scarcely ridged, the thick wall exceeding the cells in diameter.... 5. var. *lanaiense*

E. Endocarp of various shapes, often ridged, rarely strongly depressed, and then the wall thinner than the cells in diameter.

F. Calyx lobes mostly 1–3 mm. long; corolla often pubescent within; style mostly 1.5–3 mm. long; drupe always greenish-white; endocarp 2–6 mm. long, 4–10-celled............. 3. var. *sandwicense*

F. Calyx lobes mostly 3–5 mm. long; corolla glabrous (or rarely sparsely pubescent) within; style mostly 3–5 mm. long; drupe sometimes pink or purplish; endocarp 5–10 mm. long, 4–6-celled........................... 4. var. *Fauriei*

D. Leaves pubescent.

G. Hairs branched; branchlets pubescent; leaves lanceolate or elliptic-lanceolate....................... 6. var. *stellatum*

G. Hairs unbranched.

H. Branchlets glabrous; leaves often broadly elliptic, entire or remotely serrate....................... 7. var. *Degeneri*

H. Branchlets usually pubescent; leaves lanceolate.

I. Corolla not over 6 mm. long; style less than 3 mm. long...................var. *sandwicense*, pubescent form

I. Corolla over 6 mm. long; style 3 mm. long or more.......... var. *Fauriei*, pubescent form

C. Stamens constantly 4; corolla densely pubescent; leaves elliptic-spatulate, abrubtly acute............................ 9. ssp. *Wilderi*

B. Style hirsutulous; flower parts mostly 6–8; endocarp usually 7–12-celled, often sharply ridged........................... 8. ssp. *St.-Johnii*

A. Style hirsutulous (rarely glabrate in *M. Stokesii*), 4–6 mm. long; stamens 4; fruit pink or red; endocarp 3–6-celled.

J. Leaves entire; endocarp angled... 10. *M. Stokesii*

J. Leaves serrate; endocarp not or scarcely angled............................. 11. *M. rapense*

K. Calyx lobes not ciliate....... 12. var. *rapense*

K. Calyx lobes ciliate........ 13. var. *Skottsbergii*

1. **Myoporum sandwicense** A. Gray, Proc. Am. Acad. Sci. 6: 52–53. 1866.

Polycoelium sandwicense A. DC., Prodr. 11: 706. 1847 (illegitimate name).

Usually much-branched shrubs 1–3 m. high, but stature varying from prostrate (littoral form) to trees 15 m. tall. Stem usually glabrous with smooth green or olive-brown bark when young, gray and cracking into chunks when older. Leaves alternate, often lanceolate but varying from linear-lanceolate to ovate, acute to long-acuminate, entire or often crenate or serrate, decurrent-petiolate, 3.5–22 cm. long, 0.5–4 cm. wide; usually somewhat fleshy but varying from submembranous to stiff-coriaceous when dry; usually glabrous or more rarely pubescent. Flowers axillary, in clusters of 2–10, often 1 or more abortive; pedicels terete or flattened, 0.5–1.7 cm. long. Calyx lobes 4–9, mostly 5, 1–6 mm. long, broadly ovate to oblong or lanceolate, green and herbaceous or slightly scarious on the minutely glandular-denticulate margins, glandular-punctate, usually glabrous. Corolla 4–9- (mostly 5-) lobed, 4.5–12 mm. long, campanulate to funnelform, usually glandular-punctate, entirely glabrous to densely pubescent within; color pure white, white with pink-purplish splotches, or entirely pink; corolla lobes ovate-deltoid to oblong, emarginate, obtuse, or apiculate, 2–7 mm. long. Stamens inserted on the corolla, the same number as and alternate with the corolla lobes or occasionally 1 or 2 fewer; filaments flattened-subulate, 1.5–5 mm. long; anthers 0.5–1.5 mm. long, the cells confluent by a common suture and thus changing from parallel to widely divergent at anthesis. Ovary cylindric-conic to depressed-conic, 1.5–4 mm. long, glabrous, green, 4–12-celled, the base with a yellow or purple apparently nectariferous ring; style terete or flattened, 1.5–6 mm. long; stigma convex, obscurely 2–5-grooved. Drupe fleshy, the exocarp greenish-white or creamy-white, rarely pinkish or purplish; endocarp 2–10 mm. long, 2–9 mm. broad, smooth or ribbed, subglobose or variously flattened, hard and bony when mature. Seeds one in each cell, spindle-shaped, papery when dry, 2–2.5 mm. long.

The name *Myoporum sandwicense* dates from its use by Asa Gray in 1866, the original combination *Polycoelium sandwicense* A. DC. being illegitimate under the International Rules of Botanical Nomenclature, Article 60 (1). The generic name *Polycoelium* was a substitution for the earlier *Pentacoelium* of Siebold and Zuccarini, and hence was superfluous when published. According to Article 69 of the rules, Gray's adoption of the epithet *sandwicense* is treated as a new name and not as a new combination.

As here construed *M. sandwicense* embraces three rather diverse subspecies, each of which could well be treated as a species if their differences were constant. I have been reluctant to reduce *M. Wilderi* to a subspecies, but if this were not done consistency would demand the elevation of ssp. *St.-Johnii* to specific rank, and this action does not seem warranted.

2. **Myoporum sandwicense** ssp. **sandwicense.**

Myoporum sandwicense A. Gray, Proc. Am. Acad. Sci. 6: 52–53. 1866 (in part, excluding reference to *Douglas* collection).

Prostrate shrubs to tall trees. Leaves mostly lanceolate, less commonly almost linear or ovate or elliptic, never spatulate, 3.5–22 cm. long, 0.5–4 cm. broad, glabrous or pubescent. Flowers in clusters of 2–10 (mostly 3–5). Calyx mostly 5-lobed, lobes broadly ovate to oblong or lanceolate, 1–5 mm. long. Corolla mostly 5-lobed, glandular-punctate, glabrous or pubescent within, 4.5–12 mm. long. Stamens isomerous with the corolla lobes, the fifth one occasionally reduced or absent. Ovary 4–10-celled, 1.5–4 mm. long; style glabrous, 1.5–6 mm. long. Drupe creamy- or greenish-white or rarely pinkish or purplish;

endocarp 2–10 mm. long, 2–9 mm. broad, subglobose to depressed.

This extremely variable and complex subspecies is restricted to the Hawaiian Islands.

3. Myoporum sandwicense ssp. sandwicense var. sandwicense.

Pls. I, 2–6; II, 16–17, 27–30; III, 38–40

Myoporum sandwicense A. Gray, Proc. Am. Acad. Sci. 6: 52–53. 1866 (in part, excluding reference to *Douglas* and *Nuttall* collections).

Leaves mostly lanceolate to oblong or ovate lanceolate, rarely sublinear or ovate, 4–22 cm. long, 0.5–3.8 cm. broad, glabrous (except in one form). Flowers in clusters of 2–9 (mostly 3–6); pedicels 0.3–1.5 cm. long. Calyx mostly 5-lobed (rarely the lobes 4, 6, or 7); lobes broadly to narrowly ovate or oblong, 1–3 (rarely 4) mm. long. Corolla 5-lobed (rarely the lobes 6–7), glandular-punctate, glabrous or pubescent within, 4.5–8 (rarely to 9.5) mm. long. Stamens usually 5, occasionally one reduced (more rarely the number 4 or 6–8). Ovary 4–10-celled but mostly 5–7-celled; style 1.5–3 (rarely 4) mm. long. Drupe creamy-white, never pink or purplish; endocarp 2–6 (rarely 7) mm. long, mostly subglobose or top-shaped, usually ribbed.

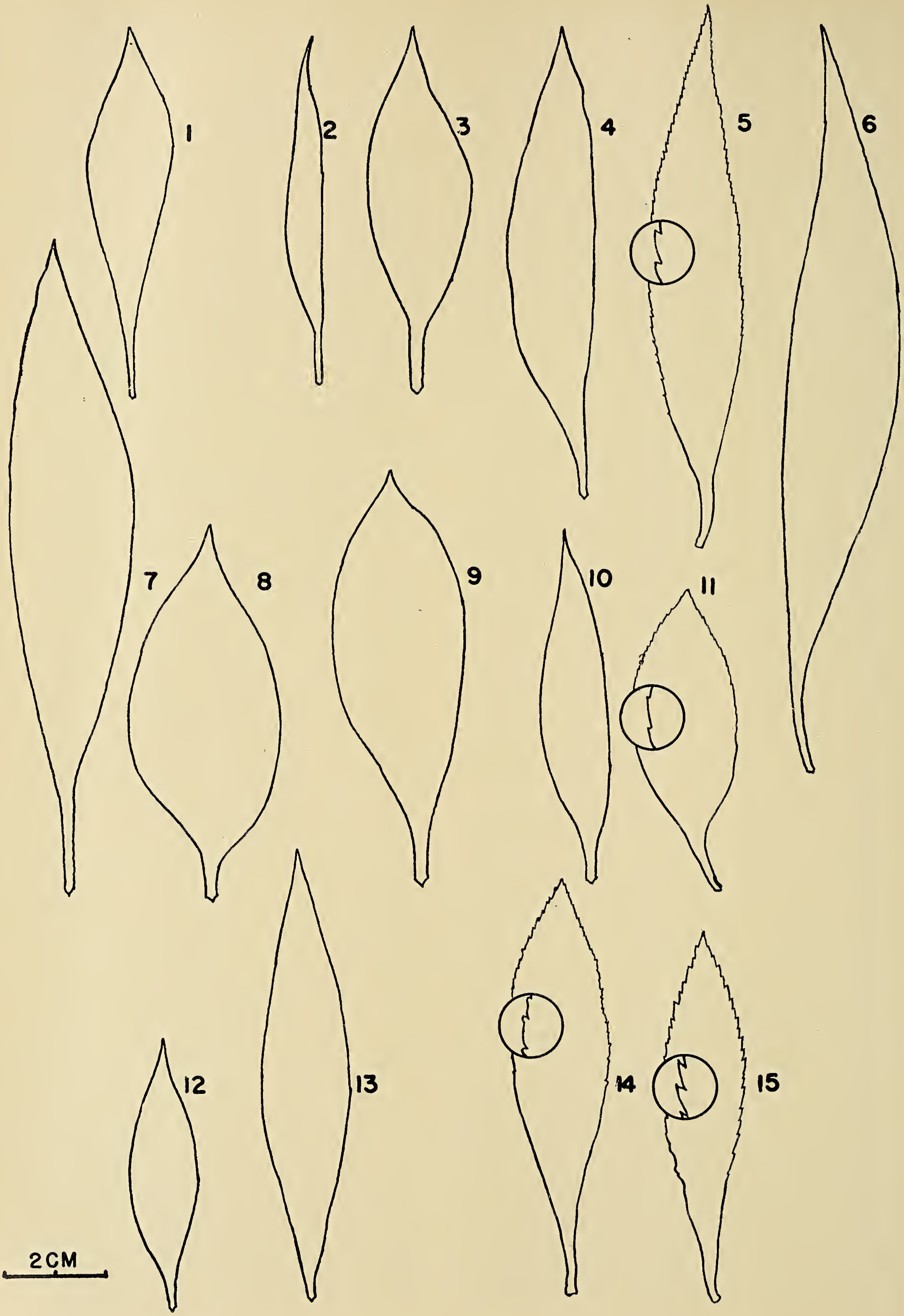
LECTOTYPE: Isles Sandwich, Oahu, *Remy 462* in the Gray Herbarium.

This extremely polymorphic variety is found at present on all the main islands except Hawaii and Kahoolawe. It is the heterogeneous residuum which remains after the more well-marked populations have been removed, and some of the forms enumerated here may warrant reappraisal when better known.

It has seemed best to arrange the various forms in a geographic sequence, first for the sake of convenience and also because forms from different islands which appear morphologically similar are most likely related not to each other but to adjacent forms on the same island. To give an idea of the correspondence and relationships of the forms, however, the following key is submitted with the caution that a clear differentiation of the forms is not possible.

Key to forms of var. *sandwicense*

A. Leaves all serrate, glabrous; style mostly 3–4 mm. long .... Molokai Form 3
A. Leaves entire or occasionally serrate or pubescent and sharply serrate; style usually not over 3 mm. long.
  B. Leaves glabrous.
    C. Stamens 4; style mostly 2.5–4 mm. long .... Oahu Form 5, Kauai Form 4
    C. Stamens mostly 5, rarely more.
      D. Style 2.5–4 mm. long; corolla glabrous, broadly campanulate, the lobes 5–7 .... East Maui Form
      D. Style mostly 1–3 mm. long; corolla often pubescent, the lobes mostly 5.
        E. Corolla lobes 6–8, corolla pubescent .... Oahu Form 4
        E. Corolla lobes mostly 5, rarely 6.
          F. Leaves large, 8–22 cm. long, often serrate; style 2–3 mm. long; corolla pubescent .... Kauai Form 1
          F. Leaves smaller, 5–14 cm. long, mostly entire; corolla glabrous or pubescent.
            G. Endocarp strongly depressed.
              H. Calyx less than 2 mm. long .... Oahu Form 3
              H. Calyx over 2 mm. long .... West Maui Form 2
            G. Endocarp more or less isodiametric, or at least not depressed.
              I. Leaves linear-lanceolate, 8–10 times as long as broad; calyx 2–3 mm. long .... Molokai Form 2
              I. Leaves mostly less than 8 times as long as broad.
                J. Leaves broadly elliptic.
                  K. Leaves rather membranous .... Kauai Form 3
                  K. Leaves fleshy, leathery when dry .... Oahu Form 1
                J. Leaves mostly lanceolate........
                  L. Leaves long-attenuate .... Kauai Form 4
                  L. Leaves acute to acuminate.
                    M. Cells of drupe 4–5; corolla mostly about 5 mm. long .... Molokai Form 1
                    M. Cells of drupe mostly 5–7, less commonly 8 or more, rarely 4; corolla often longer than 5 mm. .... Niihau Form, Kauai Form 2, Oahu Form 2, Lanai Form, West Maui Form 1
  B. Leaves mostly densely pubescent and serrate, sometimes glabrous entire leaves on the same plant .... Molokai Form 4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Specimens examined

HAWAIIAN ISLANDS (without specific locality):

Bennett (K); *Gaudichaud 39* (G-DEL, P); 1839, *Gaudichaud* (G-DEL); *Macrae* (K); *Menzies* (K); *Wilkes Expedition* (NY); "Hawaii," *Wilkes Expedition* (NY).

NIIHAU:

At foot of plateau, South East, *Stokes* (BISH, NY); south corner of plateau, *Stokes* (BISH); Kalaalaau Valley, alt. 50 ft., *St. John 22747* (BISH); Mokouia Valley, alt. 500 ft., *St. John 23592* (BISH); Paniau, 1 mile S. of, crest of windward cliff, alt. 1,200 ft., *St. John 23603* (BISH).

KAUAI:

Form 1. Leaves large, 8–22 cm. long, tending to be serrate. Stamens 5.

Waimea, seacoast, *Mann & Brigham 585* (in part) (G-BOIS, GH, NY); Waimea, Polihale, flat back of beach, *St. John et al. 22956, 22957, 22961* (BISH, T).

Form 2. Leaves mostly smaller and entire, 5.5–14 cm. long. Stamens 5.

Without locality, *Menzies* (GH); *Wawra* (G-DEL); *Wawra 2072, 2407* (W); Oct. 1916, *Rock* (BISH). Waimea, seacoast, *Mann & Brigham 585* (in part) (BISH, GH); Napali Coast, at top of beach west of Kalalau Valley, *St. John et al. 23208* (BISH, T); barren ridge, Waimea Drainage Basin, West Side, *Forbes 982.K* (BISH); Waimea, Milolii Ridge, on bare windswept headland, *St. John & Fosberg 13711* (BISH); Waimea, Polihale, rocky lowland, alt. 30 ft., *St. John et al. 22955* (BISH, T); Haeleele Valley, *Degener 9736* (DEG); northwest side of Waimea Canyon, along ditch trail at 3,500 ft., *Degener 20515* (DEG); Waimea, Kumuwela [Kumuweia] Ridge, bottom of gulch near stream, alt. 3,500 ft., *St. John, Fosberg, & Oliveira 13852* (BISH); southeast side Kumuwela Ridge, moist open forest, alt. 1,100 m., *Fosberg 12650* (BISH); Kaholuamanu, *Forbes 319.K* (BISH); same locality [Kaholuamano], *Rock? 92* (BISH), *Rock 2478* (BISH, GH, NY), *5258* (BISH), 5259 (GH).

Form 3. Leaves elliptic, rather abruptly contracted to the tip.

Without specific locality, *Remy 463* (GH).

Form 4. Like Form 2 but stamens 4.

Without specific locality, *Wawra 2299* (W).

Form 5. Leaves attenuate-acuminate, entire. Stamens 5. Drupe 6–7 mm. long.

Without locality, *Brodie* (BISH); ridge west of the Hanapepe River, *Heller 2452* (BISH, G-BOIS, G-DEL, GH, NY, P).

OAHU:

Form 1. Leaves fleshy, elliptic, up to 3 cm. wide (probably a mere ecological form).

Without locality, *Remy 461* (GH, P); Mokuleia, near sea, *Degener 9730* (DEG, NY); Moku Manu I. (islet off Mokapu Point), *Munro* (BISH).

Form 2. Leaves lanceolate. Stamens 5 or rarely 4 or 6. Drupe subglobose, 5–8-celled (up to 10-celled in specimens from Koolau Range). Styles mostly 1.5–2.0 mm. long.

Without locality: *Beechey Expedition* (G-DEL, K), *Remy 462* (GH), *Wilkes Expedition* (GH).

Waianae Range: Kaena Pt., *Bryan* (BISH); Kaena Pt., Kuaokala, *Cowan 726* (BISH); Kaena, in front of beach, alt. 15 ft., *Cowan 732, 737* (BISH); Kaena Pt., near sea,

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PLATE I

Leaf outlines of the Polynesian species of *Myoporum*.

EXPLANATION OF PLATE

M. sandwicense var. *stellatum:* (1) from *Webster 1243*, Oahu. *M. sandwicense* var. *sandwicense:* (2) from *Forbes 148.Mo*, Molokai; (3) from *Degener 9730*, Oahu; (4) from *Fosberg 13153*, Oahu; (5) from *Degener 12184*, Molokai; (6) from *Heller 2452*, Kauai. *M. sandwicense* var. *Fauriei:* (7) from *Webster & Wilbur 1775*, Hawaii; (8) from *Rock 8335*, Hawaii. *M. sandwicense* ssp. *Wilderi:* (9) from *Wilder 781*, Rarotonga. *M. sandwicense* var. *Degeneri:* (10) and (11) from *Degener 12183*, East Maui. *M. Stokesii:* (12) from *St. John & Fosberg 15956*, Raivavae; (13) from *St. John & Fosberg 15964*, Raivavae. *M. rapense* var. *Skottsbergii:* (14) from *Cuming 1430*, Tubuai. *M. rapense* var. *rapense:* (15) from *Fosberg 11525*, Rapa.

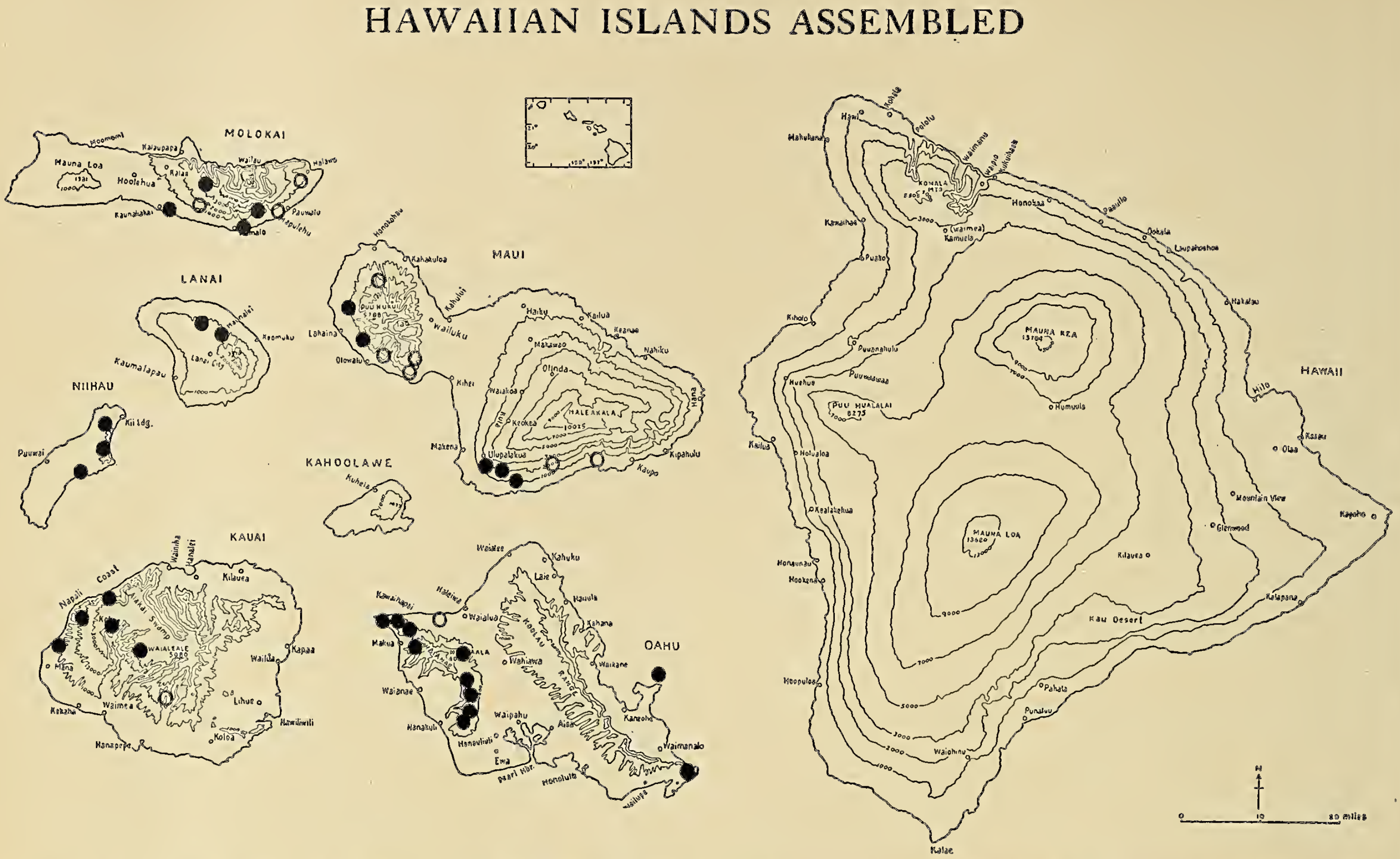

FIG. 1. Distribution of *M. sandwicense* var. *sandwicense*. Solid dots indicate exact locality, open dots approximate locality. (Base map, courtesy of Bernice P. Bishop Museum.)

Degener, Park, & Nitta 9731 (DEG); Kaena Pt., *Forbes 1652.0* (BISH, NY); bluff above Kaena Pt., alt. 60 m., *Fosberg 13153* (BISH); by railroad, Kaena Pt., alt. 15–20 ft., *Neal* (BISH); Kaena Pt., *Russ* (BISH), *Topping* (DEG); Nihoa Gulch, Mokuleia, alt. 150 ft., *Hume 307* (BISH); same locality, alt. 400 ft., *Liu* (DEG); Nihoa Gulch, Kaena, base of cliffs, alt. 400–500 ft., *St. John 11140* (BISH); near beach 1 mile east of Kaena Pt., *Webster 1077, 1079, 1080* (BISH, T), *1078* (BISH); cliffs 2 miles east of Kaena Pt., alt. 250–350 ft., *Webster 1086, 1091* (BISH, T), *1090* (BISH); at the top of the first gulch east of Kaena Pt., alt. 400 ft., *Webster 1092.A* (BISH, T), *1092.B* (near to Form 3) (BISH); cliffs 1 mile east of Kaena Pt., alt. 400 ft., *Webster & Cowan 1097* (BISH, T); near road 1 mile east of Kaena Pt., *Webster & Krauss 1096* (BISH); Kewaula Valley, arid rocky valley, *Degener, Park, & Nitta 9732* (DEG, NY); arid ravine near Kawaihapai, *Degener 2197* (DEG, NY); steep brushy wall of gulch, south side Makua Valley, alt. 500 m., *Fosberg 12350* (BISH); Mt. Kaala, forest at 2,500 ft., *Degener, Murashige, & Kerr 19736* (transitional to Form 4) (DEG); Puu Kanehoa, southeast ridge of south peak, alt. 1,900 ft., *St. John 23291* (BISH).

Koolau Range: Maunalua, Kealakipapa Valley, alt. 5 m., *Fosberg 10919* (BISH, DEG); Maunalua, east bottom of Kalama Valley, alt. 15 m., *V. O. Fosberg 93, 95* (BISH); Maunalua, head of Manuwaii Valley, alt. 180 m., *V. O. Fosberg 85* (BISH); arid rocky region west of Makapuu Head, *Degener, Park, & Hirai 9728* (DEG, G-DEL, NY); rocky lowland 1 mile southwest of Makapuu Point, alt. 10 ft., *Dunn* (BISH).

Form 3. Like Form 2 but drupe strongly depressed.

Waianae Range: cliffs 2 miles east of Kaena Pt., alt. 250–350 ft., *Webster 1081* (BISH, T); Kawaihapai Valley, alt. 400 ft., *Suehiro* (BISH).

Form 4. Like Form 2 but flower parts 6–8. Waianae Range: Kawaihapai, arid rocky region, *Degener, Park, & Topping 9729* (DEG, NY).

Form 5. Stamens invariably 4. Style 2–3 mm. long.

Waianae Mountains, *Hillebrand* (K); Waianae Range, *Hillebrand* (K); Kealia Trail, *Selling 3913* (transitional to Form 2) (S); same locality, steep brushy slope, alt. 300 m., *Fosberg 12858* (BISH); Puu Kaala, Waianae-uka, alt. 650 m., *Fosberg 12614* (BISH); same locality, alt. 2,000 ft., *St. John 12930* (BISH), *Webster & St. John 1501* (BISH, T); near Kolekole Pass, *Selling* (*Bog Survey*) *3914* (BISH, S); Popouwela, *Forbes 1593* (BISH, NY); Puu Kanehoa, east ridge, alt. 1,700 ft., *St. John 14065* (BISH); Lihue Gulch, east branch, *Forbes 1688.0* (BISH); same locality, *Russ* (BISH); Pouilihale ridge, semi-moist brushy ridge, alt. 700 m., *Fosberg 13782* (BISH); Palehua, Honouliuli, crest of ridge, alt. 2,000 ft., *St. John 11162* (BISH); Palehua, alt. 650 m., *Skottsberg 324* (S); near Mauna Kapu, *Degener 9741* (DEG).

MOLOKAI:

Form 1. Leaves narrowly lanceolate, entire, glabrous; drupe 4–5-celled.

Kaunakakai, below government road, on beach, *Wilder* (BISH, NY); east fork of Kawela Valley, *Degener 12181.B* (DEG); Kamalo, alt. 1,000 m., *Faurie 678* (BISH); Kamalo road, sea-level, *Rock 12578* (BISH); beach at Kamalo, *Rock 17137* (annotated by Rock with an unpublished varietal name) (BISH); Mapulo'u [Mapulehu], *Rock 6153* (GH, NY); Pukoo, *Faurie 679* (P); south slope of Halawa Valley, *Degener 9737* (DEG, G-DEL, NY).

Form 2. Leaves linear-lanceolate, entire, glabrous; drupe 5–8-celled.

Slopes of Puu Kolekole, *Forbes 148.Mo* (BISH, NY, P).

Form 3. Leaves oblong-lanceolate, all serrate, glabrous; drupe 4–5-celled.

North slope of Puu Kaeo, *Degener 9739* (DEG); above head of Waikolu Valley, rainy shrubby gully, *Degener 12182, 12184* (DEG); Waikolu, steep valley wall below Puu Kaeo, wet woods, alt. 3,000 ft., *St. John et al. 23431* (BISH); same locality, alt. 2,800 ft., *St. John et al. 23466* (BISH); same locality, alt. 2,000 ft., *St. John et al. 23441* (BISH); Manawai—Kahanui ridge, moist forest, alt. 600 m., *Fosberg 13392* (BISH).

Form 4. Leaves serrate, densely pubescent, or glabrous and entire leaves on the same plant.

Puu Kolekole, *Forbes 181.Mo* (BISH); east fork of Kawela Valley, three distinct forms growing together on dry rocky slope, *Degener 12181.A* (serrate-pubescent), *12181.C* (entire, pubescent), *12181.D* (entire, glabrous) (DEG).

LANAI:

Without specific locality, *Forbes* (BISH); flats above head of Hawaiilanui Gulch, alt. 500 m., *Fosberg 12523* (BISH); Maunalei Gulch, dry basalt talus, alt. 800 ft., *St. John, Eames, & Hosaka 18812* (BISH); Limestone Point, *Munro* (BISH) (identification doubtful).

WEST MAUI:

Form 1. Leaves narrowly lanceolate; drupe subglobose or broadly ovoid.

Without definite locality, *Mann & Brigham 387* (G-DEL, GH, NY); Lahainaluna, Aug. 1910, *Forbes* (BISH, NY); south ridge of Laniupoko Valley, alt. 1,000 ft., *St. John & Catto 17705, 17706* (BISH); Olowalu Valley, *Forbes 2325.M* (BISH, NY); from Papawai Point toward Puu Anu through Manawainui Gulch, *Degener 9742* (DEG, NY); Pohakea Gulch, arid windy slope, *Degener 9743* (DEG, G-DEL, NY); Wailuku, gulch south of Waikapuu [Waikapu] Valley, *Skottsberg 783* (BISH, S).

Form 2. Like Form 1 but drupe strongly depressed.

Honokahau [Honokohau] Drainage Basin, *Forbes 477.M* (BISH, NY, P).

EAST MAUI:

The single form is much like West Maui

Form 1 but the style is longer and the flower parts may be more than 5.

"Sandwich Islands," *Hillebrand* (probably from East Maui) (GH); East Maui, *Hillebrand* (K); Haleakala, *Hillebrand* (K); Kula, open rocky Kula land, alt. 1,000 ft., *Wilder 282* (BISH); near Ulupalakua, *Degener 9740* (DEG, G-DEL, NY); southwest slope of Haleakala, above Kanaio, *Alexander & Kellogg 5353* (BISH); Hokukano, arid lava waste, *Degener & Clay 19408* (DEG); Nakaaha, dryish lava waste, *Degener 19306* (DEG); Nuu, rough lava flow, *Forbes 1910.M* (BISH).

The forms of var. *sandwicense* range in value from those which are probably ecological modifications to those which approach varietal distinction. Oahu Form 5 was at first thought to be possibly a variety because of its flowers with only four stamens, but the specimen collected by St. John (number *23291*) from the center of its range at Puu Kanehoa shows that the stamen character is not constant.

The most perplexing forms of var. *sandwicense* are those found on Molokai, and additional field work must be done before a final systematic arrangement of them can be made. Molokai Form 3 is on the borderline of varietal status, but it is being kept as a form at present because its best character—constantly and sharply serrate leaves—does not distinguish it from populations on other islands within which serrate leaves are not uncommon.

4. **Myoporum sandwicense** ssp. **sandwicense** var. **Fauriei** (Lévl.) Kraenzlin, Fedde Repert. Sp. Nov. Beih. 54: 21. 1929.
Pls. I, 7–8; II, 18–19, 31; III, 41.

Myoporum Fauriei Lévl., Fedde Repert. Sp. Nov. 11: 63. 1912.

Leaves ovate-lanceolate to ovate or elliptic, acute or acuminate, entire or serrate, 5–17 cm. long, 0.9–4 cm. broad, mostly coarse and brittle-coriaceous but often thinner, glabrous or rarely pubescent. Flowers 2–5 to an axil;

HAWAIIAN ISLANDS ASSEMBLED

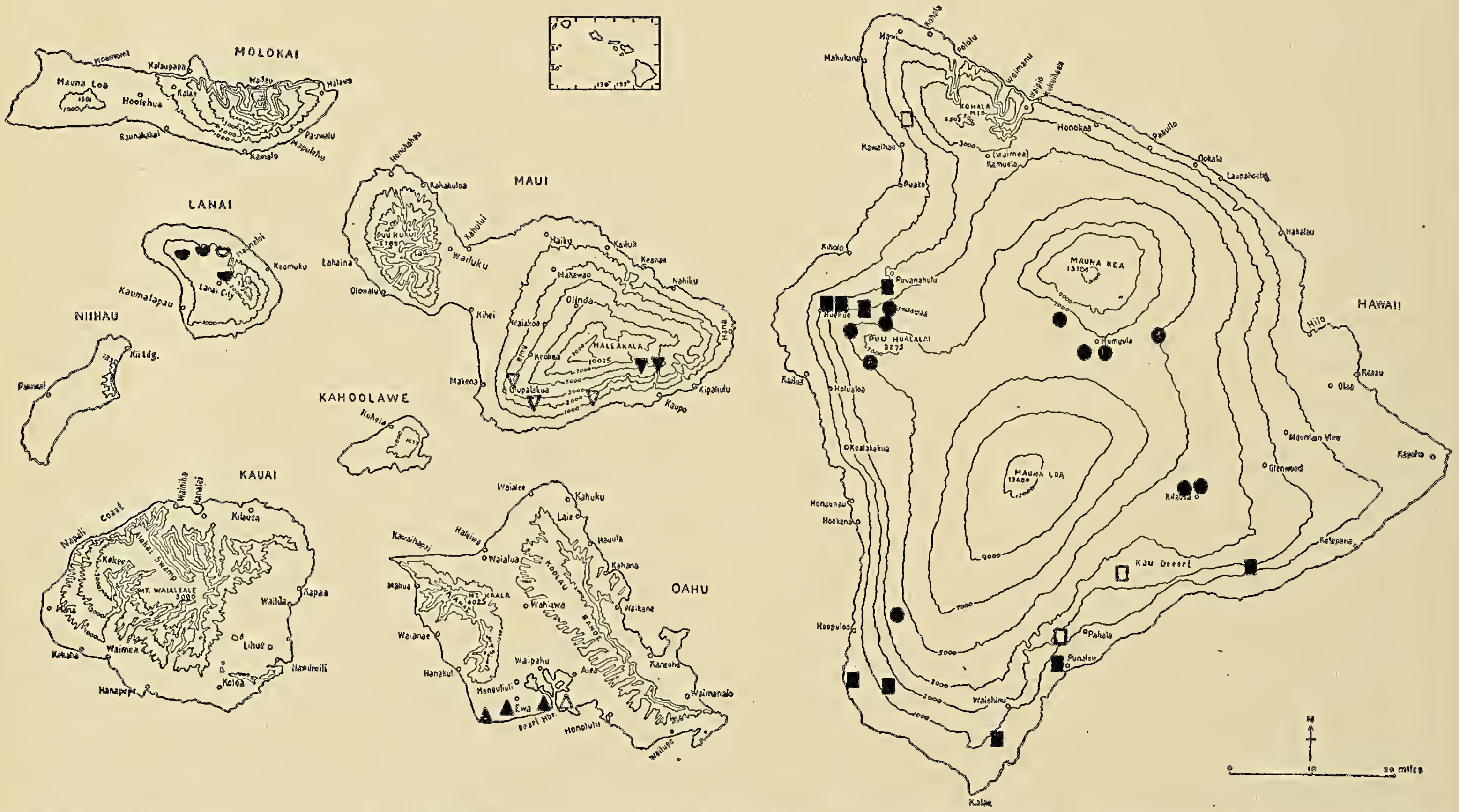

FIG. 2. Distribution of the other Hawaiian groups of *M. sandwicense*. Circles represent var. *Fauriei*, squares ssp. *St.-Johnii*, erect triangles var. *stellatum*, inverted triangles var. *Degeneri*, semicircles var. *lanaiense*. Solid symbols indicate exact locality, open symbols indicate approximate locality; specimens of really doubtful locality and those examined after the completion of this plate are not mapped. (Base map, courtesy of Bernice P. Bishop Museum.)

pedicels 0.5–1.7 cm. long. Calyx lobes 5 (rarely 6), 2.5–6 (mostly 3–5) mm. long, ovate-lanceolate to lanceolate. Corolla 5-lobed (rarely 6-lobed), 6.5–12 mm. long, glabrous or more rarely sparsely pubescent. Stamens mostly 5, rarely 6, often with one stamen reduced or sometimes entirely wanting. Ovary 2.5–4 mm. long, 4–6-celled (rarely 7-celled); style 2.5–6 (mostly 3–5) mm. long, glabrous. Drupe creamy-white or often pinkish or rarely purplish; endocarp broadly ovoid, 5–10 mm. long, not prominently ribbed.

TYPE: "Sandwich: Hawai, Maunakea, 2,000 m., juill. 1909 (Faurie, 677)." An isotype is in the Bishop Museum.

This variety is limited to the upper dry forest (altitude 4,000 feet to the timber line) on the island of Hawaii.[3] It is conspicuous because of its large leaves, flowers, and fruit and seems a distinct entity in spite of its overlap of characters with var. *sandwicense.* Usually var. *Fauriei* has longer calyx lobes, styles, and drupes than var. *sandwicense*, but this does not always hold and then characters such as the number of cells in the drupe, the lack of corolla pubescence, and the general leaf aspect of var. *Fauriei* must be considered. Var. *Fauriei* appears to be the most primitive group of ssp. *sandwicense* and closely resembles ssp. *Wilderi* in flower size and drupe characters. Its retention of the pinkish drupe color and its flowers which often lack the fifth stamen are primitive characters of special significance. Within var. *Fauriei* one finds a great deal of polymorphism, there being large and small flowers, long elliptic-lanceolate and short ovate leaves; but I have not been able to segregate these types into populations.

Specimens examined

HAWAII:

Form 1. Leaves glabrous; flower parts in 5's; cells of drupe 4–6.

"Hawaiian Islands" (no definite island cited): *Collector unknown* (BISH); Bonite voyage, *Gaudichaud* (GH); *Hillebrand* (K); *Mann & Brigham 568* (BISH).

Hawaii, without definite locality, *Challenger Expedition* (K), *Wilkes Expedition* (GH); South Hilo District, Waiakea, 22 miles up Saddle Road, alt. 5,100 ft., *St. John, Cowan, & Rogers 22391* (BISH); North Hilo District, Humuula, Puu Huluhulu, alt. 6,750 ft., *Bryan* (BISH); same locality, alt. 6,760 ft., *St. John et al. 23934, 23935* (glabrous sucker shoot from same plant as *23934*), *23936* (pubescent sucker shoot from same plant) (BISH); Humuula, Saddle Road 1 mile south of Omaokoili, south slope of cinder cone, alt. 6,650 ft., *St. John, Cowan, & Rogers 22379, 22380* (BISH); Pohakuloa, alt. 6,500 ft., *Bryan* (BISH); slopes of Mauna Kea above Waikii, *Rock 8335* (BISH, GH); Puuwaawaa, *Austin* (BISH), *Munro* (BISH); Kona, above Huehue, *Rock 3489* (BISH, GH); Hualalai, Puu Laalaau, alt. 6,300 ft., *Kondo* (BISH); Puu Hualalai, 4,100–6,500 ft. alt., *St. John et al. 11394* (BISH); Kona, Captain Cook, south of Papaloa, alt. 5,000 ft., *Degener & Murashige 20335* (DEG); Kealakekua, Greenwell Ranch, alt. 4,500 ft., *St. John & Hatheway 23982* (BISH); South Kona District, Alika Homesteads, Koa Mill, alt. 4,500 ft., *St. John et al. 22486* (BISH); Kilauea, *Forbes ?* (BISH), *Forbes, Brigham, & Thompson* (BISH, P); Hawaii National Park, Kipuka Ki, alt. 4,300 ft., *Webster & Wilbur 1702, 1703, 1704, 1705, 1706, 1707* (BISH, T); Hawaii National Park, Bird Park [Kipuka Puaulu], alt. 4,000 ft., *Degener 9735* (DEG, NY); same locality, *Bog Survey 3254* (S), *Eastwood* (NY), *St. John et al. 11260, 11266* (BISH), *Setchell* (S), *Skottsberg 541* (BISH, S), *Webster & Wilbur 1775, 1776, 1777* (BISH, T).

Form 2. Leaves pubescent; flower parts in 5's; cells of drupe 4–6.

North Hilo District, Humuula, Puu Huluhulu, open woods on cinder hill kipuka, alt. 6,570 ft., *St. John et al. 23944* (BISH).

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[3] Kraenzlin (1929: 21) erred in referring a collection from the New Hebrides (Herb. Boissier) to this variety. I have seen the material, and although it is too fragmentary to determine positively, there is no reason to believe that it represents *M. sandwicense.*

Form 3. Leaves pubescent; flower parts 6–7; cells of drupe 7–9.

Puuwaawaa, *Rock 3800* (BISH, NY). In several respects this form is intermediate between var. *Fauriei* and ssp. *St.-Johnii.*

5. **Myoporum sandwicense** ssp. **sandwicense** var. **lanaiense** Webster, var. nov.

Pls. II, 21, 33; III, 43

Drupa depressi-conica; endocarpium non costatum.

Leaves lanceolate, acuminate, entire, glabrous, 6–13.5 cm. long, 0.8–1.8 cm. wide. Flowers 2–4 per axil; pedicels 0.7–1 cm. long. Calyx lobes 5, 2–3 mm. long, ovate-acuminate. Corolla 5-lobed, 5–8 mm. long, glabrous or pubescent, the tube 2.5–4 mm. long. Ovary about 2 mm. long; style 1.8–3 mm. long. Drupe probably whitish in color; endocarp depressed-conic or hemispheric in outline, not or scarcely ridged, 3–4.5 mm. high, 6–9 mm. broad, 5–7-celled.\

TYPE: Mahana forehills, Lanai, July 1910, *Rock 8119,* in the Bishop Museum Herbarium. Isotypes are in the Gray Herbarium and Naturhistorisches Museum, Vienna.

This variety, named for the island on which it occurs, is apparently now restricted to the dry forest near Kanepuu at the northwest end of the island. Ordinarily it is easily distinguished from var. *sandwicense* by its strongly depressed endocarp. Rarely, plants of var. *sandwicense,* such as *Webster 1081* from Oahu and *Forbes 477.M* from Maui, may have depressed endocarps which appear superficially similar, but these are easily distinguished in cross section by their thinner walls (compare Figs. 39 and 43).

The status of var. *sandwicense* on Lanai is rather uncertain. Judging from the few collections at hand, it seems to occupy a lower altitudinal zone than var. *lanaiense,* but further collecting will be necessary before its distributional relationship to var. *lanaiense* will become clear.

Specimens examined

LANAI:

Koa dry forest, Lanai, *Munro 61* (BISH, NY); plateau on lee side of island, alt. 600 m. (?), *Wilder 90* (BISH); xerophytic forest near Kanepuu, *Fosberg 12551* (BISH); Kanepuu, Kaa, alt. 1,600 ft., *St. John, Eames, & Hosaka 18803* (BISH); same locality, alt. 1,700 ft., *St. John & Cowan 22624* (BISH); flats above head of Hawaiilanui Gulch, alt. 500 m., *Fosberg 12525* (BISH); Poomai [= Paoma?], *Munro* (BISH); Mahana Valley, *Munro 171½* (BISH); Mahana forehills, *Rock 8119* (BISH, GH, W); mountains near Koele, *Forbes 91.L* (BISH).

6. **Myoporum sandwicense** ssp. **sandwicense** var. **stellatum** Webster, var. nov.

Pls. I, 1; II, 20, 32; III, 42

Prinastrum cauliflorum Nutt. ex Gray, Am. Acad. Sci. 6: 52. 1866 (herbarium name published in synonymy).

Folia hirtella, ramuli hirtelli; pili ramosi.

Branchlets and leaves pubescent with branched hairs, somewhat glabrescent with age; leaves elliptic-lanceolate, usually entire, 4–9 cm. long, 0.7–2.2 cm. broad. Calyx mostly 5-lobed, pubescent, sepals 1.2–2.5 mm. long. Corolla 5-lobed (rarely 6-lobed), 5–7 mm. long, glabrous or pubescent within, the glandular dots rather inconspicuous. Stamens mostly 4 or 5, if 5 then often one reduced. Ovary 2–2.5 mm. long; style 2–2.8 mm. long. Drupe creamy-white; endocarp subglobose, ridged, 3–5 mm. in diameter, 5–7-celled.

TYPE: Oahu, Ewa coral plain near Barbers Point, alt. 10 ft., *Webster 1243,* in the Bishop Museum Herbarium (isotype in the University of Texas Herbarium).

This distinctive variety is now restricted to the low plain of emergent coral at the southwestern corner of Oahu. It is known from Kauai on the basis of a single collection by Nuttall, but has not been collected on that island in the century since then. If Nuttall's rather questionable locality was correct, the variety has evidently become extinct on

Kauai. On Oahu it originally grew from the mouth of Pearl Harbor to Barbers Point, but it has been exterminated over much of this range by the encroachment of military establishments. In the vicinity of the lighthouse it is still quite abundant, however, and will continue to persist unless the vegetation is entirely removed. Ecologically, it must be highly specialized, as it has become adapted to a calcareous substrate quite different from the lateritic or basaltic soils on which the other varieties grow.

Although this variety superficially resembles var. *Degeneri* in the pubescent leaves, it has been independently derived, probably from Oahu Form 5 of var. *sandwicense*. This relationship is especially evident in the fact that var. *stellatum* shows the tendency toward the loss of the fifth stamen which is fully expressed in the form from the Waianae Range.

The name of this variety alludes to the appearance of the branched hairs, a character unique in the genus as far as I can determine.

Specimens examined

KAUAI:

Atooi [=Kauai], *Nuttall* (K).

OAHU:

Honouliuli, Barbers Point coral plain, alt. 10 ft., *Cowan 787*, *788* (BISH); same locality, *Degener & Park 9727* (DEG), *Egler 37–268* (BISH), *Hosaka 1359* (BISH), *Pollock* (*F. Brown's*) *1278* (BISH), *Rock 17038* (BISH, labeled with an unpublished varietal name), *Setchell* (GH), *Webster 1243*, *1244*, *1250* (BISH, T), *1245* (BISH), *1249* (T); between Barbers Point and Pearl Harbor, along beach, *Degener & Park 9733* (DEG); Ewa, below Magnetic Observatory toward beach, *Egler & Hosaka 37-419* (BISH); Puuloa, 1909, *Stokes* (BISH); east side of Pearl Harbor, *Stokes* (BISH).

7. **Myoporum sandwicense** ssp. **sandwicense** var. **Degeneri** Webster, var. nov.

Pl. I, 10–11

Folia elliptica hirtella serrata; pili simplici; ramuli glabri.

Branchlets glabrous. Leaves mostly elliptic, less commonly lanceolate, pubescent, the hairs unbranched, entire or serrate, 4–9 cm. long, 1–2.5 cm. broad. Flowers 5–6 per axil. Calyx lobes 5, glabrous or pubescent, 1.5–3.5 mm. long. Corolla glabrous or pubescent within, 5–7.5 mm. long. Stamens 5, rarely 4 or 6. Ovary 2–3.5 mm. long; style 2–5 mm. long. Drupe color unknown, presumably white; endocarp 5–9 mm. long, 5–7-celled.

TYPE: East Maui, north mauka of Ulupalakua, *Degener 12183*, in the Bishop Museum Herbarium.

This variety occurs on the dry leeward slopes of Haleakala, East Maui, from near Ulupalakua to the Kaupo Gap; a form from Molokai is referred here for convenience. It is named for Mr. Otto Degener, long a student of the Hawaiian *naio*, who illustrated it in his book, *Plants of Hawaii National Park*.

Specimens examined

MOLOKAI:

Probably near Kaluaaha, *Degener 9738* (DEG, NY).

EAST MAUI:

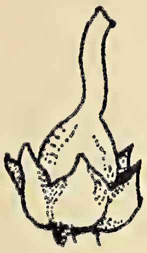
North mauka of Ulupalakua, *Degener 12183* (BISH, DEG); Auhi [=Auwahi], Ulupalakua, *Munro 385* (BISH); Kaapilopilo and Kapakahawai gulches, *Forbes 1940.M* (BISH); Waiopaa [=Waiopai] Ranch, *Forbes 1875.M* (BISH); Haleakala, Kaupo Gap, *Forbes 1105.M* (BISH); Haleakala, south of Kuiki along east side of Kaupo Gap, *Degener 17600* (NY).

Although the plant from Molokai is placed in var. *Degeneri* for convenience, it probably has arisen independently of the Maui plants and may represent a different variety. However, until the confusing forms from Molokai are better understood, it seems unwise to describe any new varieties from there.

8. **Myoporum sandwicense** ssp. **St.-Johnii** Webster, ssp. nov.

Pls. II, 22, 34–35; III, 44

Petala et sepala plerumque 6–8; stylus hirtellus; drupa plerumque 7–12-locularis.



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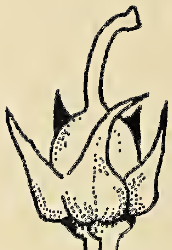

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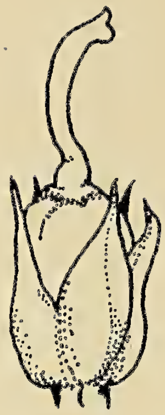

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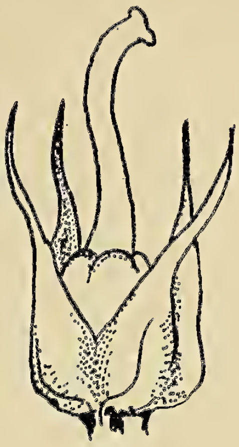

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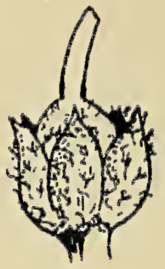

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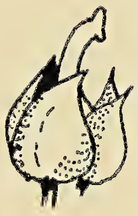

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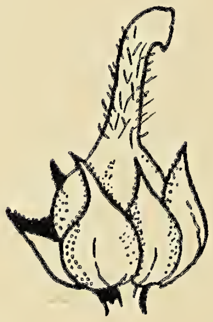

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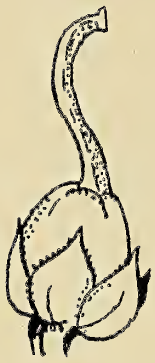

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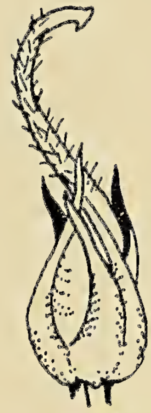

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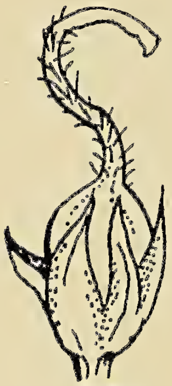

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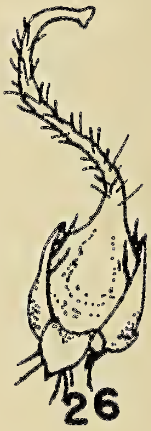

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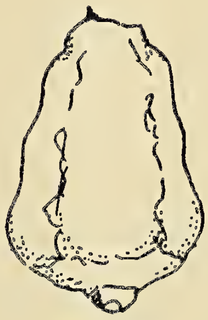

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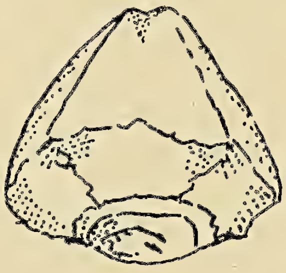

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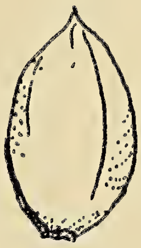

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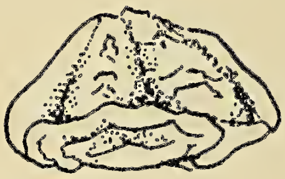

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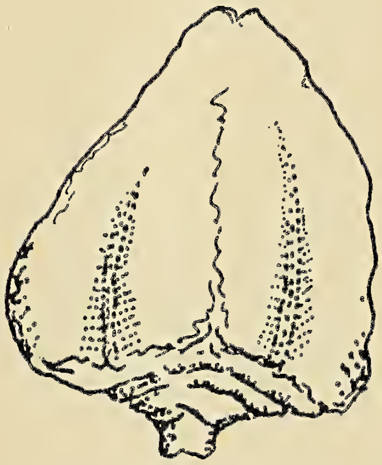

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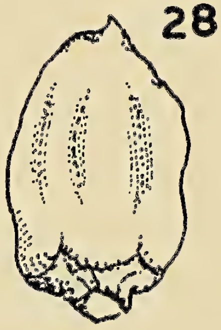

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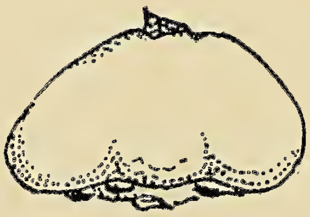

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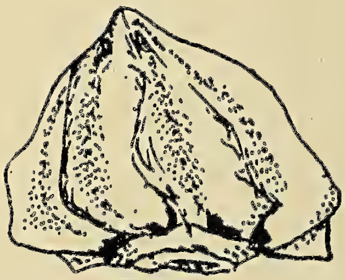

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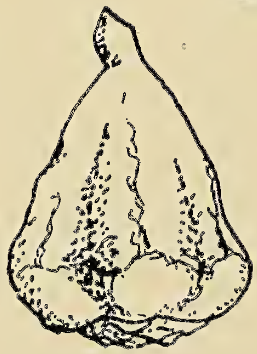

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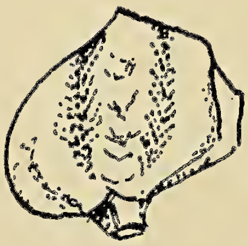

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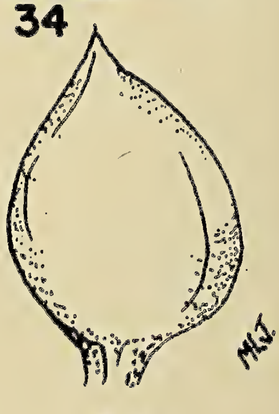

37

Shrubs to small trees, 2–8 m. high. Leaves mostly oblong-lanceolate, entire, glabrous, 4–15 cm. long, 0.5–3 cm. broad. Flowers 3–8 per axil; pedicels 0.6–1.2 cm. long. Flower parts varying from 5–9 but mostly 6–8, the sepals equal to or less than the number of corolla lobes. Sepals 1–3 mm. long. Corolla 5–8.5 mm. long, usually densely pubescent within, gladular spots absent or very few. Stamens usually 5–9 (very rarely less than 5), the same number as or less than the number of corolla lobes. Ovary 2–3 mm. long; style hirsutulous, 1.7–3.5 (mostly 2–3) mm. long. Drupe creamy-white; endocarp usually strongly ridged, more or less laterally compressed, 3–8 mm. long, 3.5–8 mm. broad, 5–13-celled but typically 7–12-celled.

TYPE: Hawaii, Kaupulehu, 2–3 miles east of Huehue, alt. 2,000 ft., *Webster & Wilbur 1835*, in the Bishop Museum Herbarium (isotype in the University of Texas Herbarium).

This polymorphic subspecies is restricted to the lower dry forests on the island of Hawaii. In its possession of a hirsutulous style it is unique among the groups within *M. sandwicense*, and it is further well marked by its large number of perianth parts, reduction of glandular spots on the corolla, and many-celled, sharply ribbed, endocarp. Morphologically, the typical form (Form 1) is fully as distinct from the other varieties of *M. sandwicense* as many species of this genus are from one another. But the typical form intergrades with Form 2, which may be almost indistinguishable from some forms of var. *sandwicense*. This is especially true of specimens from the vicinity of Punaluu in the Kau District, but because they occur in the same area as plants of Form 1 and apparently are intermixed with them, it seems preferable to regard them as merely aberrant individuals of ssp. *St.-Johnii*, which for some reason (possibly they are remnants of an ancient population of var. *sandwicense* ?) are especially common in this vicinity.

This group is named for Dr. Harold St. John of the University of Hawaii, who suggested the study of *Myoporum* and whose assistance has greatly helped to overcome the disadvantages of completing this work at a distance from the Hawaiian Islands.

Specimens examined

HAWAIIAN ISLANDS (without specific locality):

Douglas 21 (K), *Douglas* (W).

HAWAII:

Form 1. Style hirsutulous and flower parts mostly 6–8. Cells of endocarp 7–13.

North Kona, *Alexander & Kellogg 5367* (BISH); vicinity of Huehue near main road, *Bog Survey 3213* (BISH, S); between Puuwaawaa and Huehue, *Degener 2210* (DEG); Puuwaawaa, *Degener 9726* (DEG, NY), *Nishina (Degener's) 9744* (DEG, NY); 2.3 miles northeast of Huehue Ranch House, Kaupulehu, alt. 2,000 ft., *St. John et al. 22525* (BISH);

PLATE II

Reproductive structures of the Polynesian species of *Myoporum*.

EXPLANATION OF PLATE

Mature pistils (FIGS. 16–26).

M. sandwicense var. *sandwicense:* (16) from *Webster 1097*, Oahu; (17) from *Heller 2452*, Kauai. *M. sandwicense* var. *Fauriei:* (18) from *Webster & Wilbur 1706*, Hawaii; (19) from *Webster & Wilbur 1702*, Hawaii. *M. sandwicense* var. *stellatum:* (20) from *Degener 9727*, Oahu. *M. sandwicense* var. *lanaiense:* (21) from *Rock 8119*, Lanai. *M. sandwicense* ssp. *St.-Johnii:* (22) from *Webster & Wilbur 1835*, Hawaii. *M. sandwicense* ssp. *Wilderi:* (23) from *Wilder 781*, Rarotonga. *M. Stokesii:* (24) from *St. John & Fosberg 15947*, Raivavae. *M. rapense* var. *rapense:* (25) from *St. John & Fosberg 15280*, Rapa. *M. rapense* var. *Skottsbergii:* (26) from *Cuming 1430*, Tubuai.

Side view of endocarps (FIGS. 27–37).

M. sandwicense var. *sandwicense:* (27) from *St. John et al. 23208*, Kauai; (28) from *Degener 9729*, Oahu; (29) from *Degener 9737*, Molokai; (30) from *Forbes 477.M*, West Maui. *M. sandwicense* var. *Fauriei*: (31) from *Webster & Wilbur 1706*, Hawaii. *M. sandwicense* var. *stellatum:* (32) from *Degener 9727*, Oahu. *M. sandwicense* var. *lanaiense:* (33) from *Rock 8119*, Lanai. *M. sandwicense* ssp. *St.-Johnii:* (34) from *Webster & Wilbur 1835*, Hawaii; (35) from *Degener 2211*, Hawaii. *M. Stokesii:* (36) from *Fosberg 11784*, Raivavae. *M. rapense* var. *rapense:* (37) from *St. John & Fosberg 15280*, Rapa.

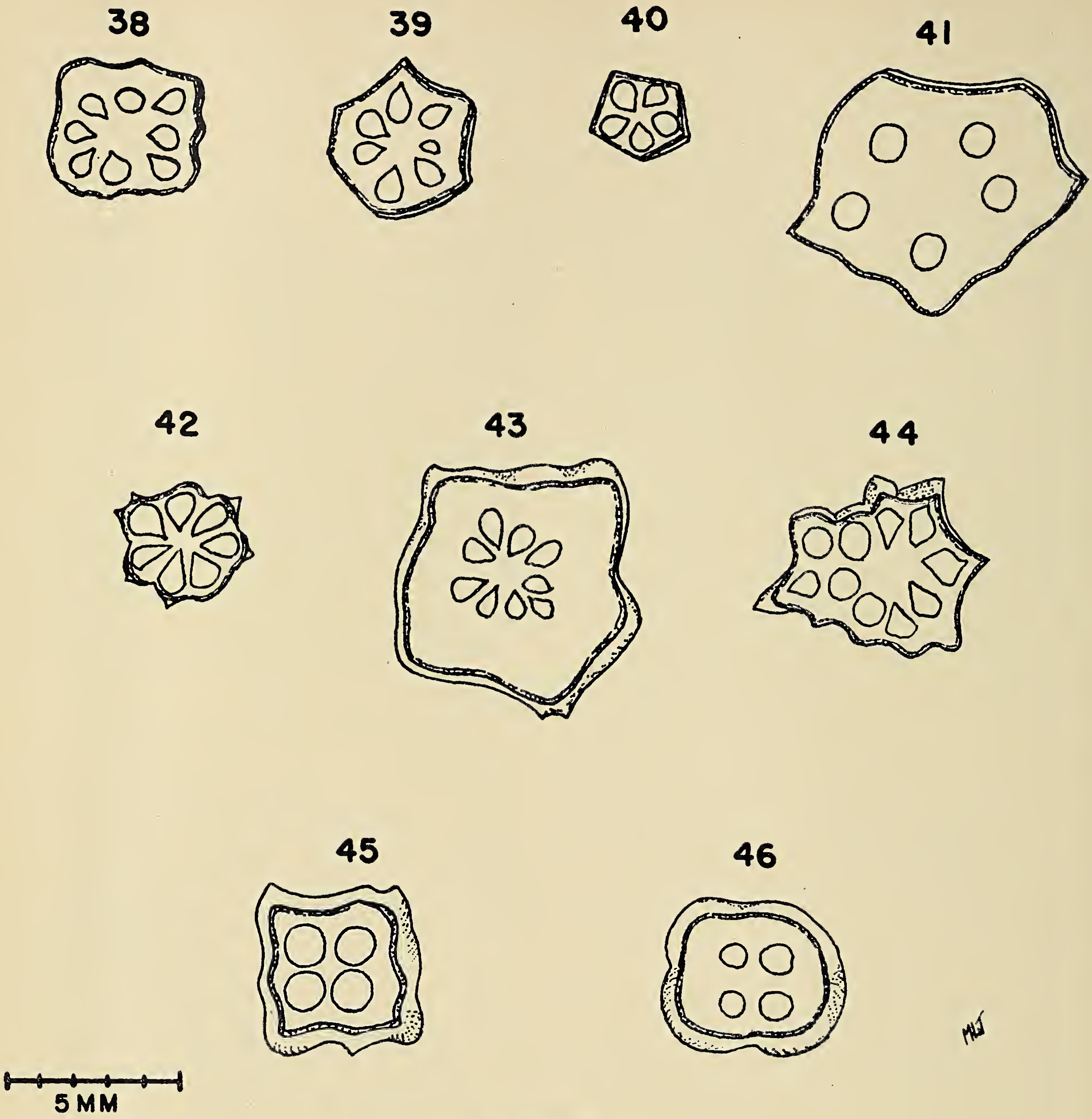

PLATE III

Reproductive structures of the Polynesian species of *Myoporum*.

EXPLANATION OF PLATE

Endocarps in cross section.

M. sandwicense var. *sandwicense:* (38) from *V. O. Fosberg 93*, Oahu; (39) from *Webster 1081*, Oahu; (40) from *Degener 9737*, Molokai. *M. sandwicense* var. *Fauriei:* (41) from *Webster & Wilbur 1704*, Hawaii. *M. sandwicense* var. *stellatum:* (42) from *Degener 9727*, Oahu. *M. sandwicense* var. *lanaiense:* (43) from *Fosberg 12525*, Lanai. *M. sandwicense* ssp. *St.-Johnii:* (44) from *Webster & Wilbur 1835*, Hawaii. *M. Stokesii:* (45) from *St. John & Fosberg 15956*, Raivavae. *M. rapense* var. *rapense:* (46) from *Fosberg 11525*, Rapa.

Puuwaawaa, 4 miles southwest of Puu Anahulu, alt. 2,000 ft., *Webster & Wilbur 1874, 1883, 1895* (BISH, T); Puuwaawaa, 3 miles west of Puuwaawaa Hill, alt. 3,000 ft., *Webster & Wilbur 1852, 1857* (BISH, T); Kaupulehu, 2–3 miles east of Huehue, alt. 2,000 ft., *Webster & Wilbur 1835* (BISH, T); Keahuolu, alt. 400 ft., on aa in dry scrub, *St. John & Lane 23978* (BISH); Kapua ?, near the sea, *Bryan* (BISH); Kapua, on kipuka south of Hanakeaumoe triangulation point, near sea level, *Bryan 761* (BISH); Manuka Mauka, alt. 750–1,750 ft., *St. John et al. 11326* (BISH); Kau, halfway between Kaalualu and Waiohinu, *Degener 9734* (DEG, NY); old aa flow, Hilea, *Russ* (BISH); Kau District, Ninole, Wailua Ninole, basalt flow near shore, alt. 15 ft., *St. John, Hatheway, & Morton 23950* (BISH); Punaluu, *Degener & Wiebke 2207* (DEG, NY); on aa flow, Punaluu, alt. 500 ft., *Neal* (BISH); Hawaii National Park, Bird Park, *Degener 9725* (DEG); Naaulu Forest, Kealakomo, alt. 1,700 ft., *Fagerlund & Mitchell 800* (BISH).

St. John et al. 23950 has the hirsutulous style typical for the subspecies but is remarkable in having the stamen number highly variable and reduced to 2–3 in the majority of flowers. The locality of *Degener 9725* should be regarded with suspicion because Bird Park has been visited many times by botanists, and only var. *Fauriei* has been collected there.

Form 2. Style very sparsely hirsutulous or glabrous; flower parts mostly 5–6; cells of endocarp 5–7.

Seventeen miles from Kohala toward Waimea, *Degener & Wiebke 2208* (DEG, NY); Puu Keekee, *Degener, Greenwell, & Murashige 20020* (DEG); 20 miles from Waimea toward Kona, *Degener & Wiebke 2211* (DEG, NY); Puuwaawaa, *Forbes 49.H* (BISH); Kau Desert 25 miles west of Kilauea, *Degener & Wiebke 2209* (G-DEL, NY); Kau District, Punaluu, *St. John et al. 11316* (BISH); same locality, *St. John, Cowan, & Rogers 22426* (BISH).

Degener, Murashige, & Greenwell 20019 (DEG), collected near Na Puukulua, is sterile and has serrate-pubescent "juvenile" leaves, but since it was found near number *20020* it probably belongs here.

9. **Myoporum sandwicense** ssp. **Wilderi** (Skottsberg) Webster, comb. nov.

Pls. I, 9; II, 23

Myoporum Wilderi Skottsberg, Acta Horti Gotob. 8: 165–166. 1933.

Shrubs or small trees. Leaves spatulate-elliptic or obovate-elliptic, acute or apiculate, glabrous, entire, 5–10.5 cm. long, 1.8–3.3 cm. wide. Flowers 3–4 per axil; pedicels 0.8–1 cm. long, flattened. Calyx 5-lobed, glandular-dotted, glabrous, the lobes mostly 1.5–2 mm. long. Corolla white, 7.5–9 mm. long, glandular-spotted, pubescent within, 5-lobed. Stamens 4 (sometimes with traces of a fifth according to Skottsberg). Ovary globose-pyriform, about 3 mm. long; style 3–4.5 mm. long, curved at the base, glabrous. Drupe color unknown (probably purplish or reddish); endocarp top-shaped, about 5–6 mm. long, 4–6-celled.

TYPE: Rarotonga, *Wilder 781*, in the Bishop Museum Herbarium.

This subspecies is cultivated by the natives of Rarotonga, in the Cook Islands of southern Polynesia, and has been found in the wild state only on the nearby island of Mangaia. It is fairly well distinguished from the other two subspecies by its leaf shape and by its flowers with only 4 stamens. However, most of the characters given by Skottsberg (1933: 155) to separate *M. Wilderi* from *M. sandwicense* are not applicable when a large amount of material of the latter species is examined. Hairy corolla lobes occur in most of the Hawaiian varieties, and the density of the pubescence may be as great as in the Rarotongan plant. The constant absence of the fifth stamen in the Cook Island population seems like a good distinction, but the form of var. *sandwicense* from the Waianae Range of Oahu usually lacks the fifth stamen, and similarly reduced flowers are not uncommon in var. *stellatum* and var. *Fauriei.* The length of the style does not distinguish Skottsberg's species because the style in var. *Fauriei* reaches 5 mm. and more in length. There remains the leaf shape to fall back upon, and although this is rather distinctive in ssp. *Wilderi*—the rounded apex of the elliptic leaf being rather abruptly contracted into an apiculate tip—it is variable even on the type specimen and does not seem to be a character of specific value.

Perhaps the best distinguishing character for ssp. *Wilderi* is that its flowers have an odor so noticeable that the plant is cultivated for perfume. In this respect the subspecies resembles the strongly scented Austral Island plants and contrasts with the relatively odorless Hawaiian plants. The basal curvature of the style is another link between the Cook Island and Austral Island plants; but this character is probably dependent on the length of the style and is of no great intrinsic significance.

Specimens examined

COOK ISLANDS:

Rarotonga, *Wilder 781* (BISH, NY); Mangaia, Nov. 1928, *Graham* (BISH).

10. **Myoporum Stokesii** F. Brown, Bishop Mus. Bul. 130: 277–278, fig. 41. 1935. Pls. I, 12; II, 24, 36; III, 45

Shrubs or trees, 1–5 m. high. Leaves elliptic-lanceolate, entire, glabrous, 3.5–9 cm. long, 0.5–1.7 cm. broad, acute, apiculate, or attenuate-acuminate, alate-petiolate. Flowers 1–3 (rarely 4) per axil, sometimes accompanied by 1 or more small abortive flowers; pedicels 0.7–1.4 cm. long. Calyx 5-lobed, glandular-dotted; calyx lobes 2–4 mm. long, entire-margined. Corolla pure white or pink-spotted in the throat, rather heavily fragrant, 9–12 mm. long, pubescent within. Stamens 4. Ovary 2.5–3.5 mm. long; style hirsutulous (rarely almost or quite glabrous), curved at the base, 4–6 mm. long when mature. Drupe translucent pink to red; endocarp turbinate, ridged, 4–6 (mostly 5) mm. long, 3–6-celled but mostly 4-celled.

TYPE: Raivavae, Matotea, alt. 78 m., April 28, 1922, *Stokes 90*, in the Bishop Museum Herbarium.

This species, known from a single island, is closely related to *M. rapense*. Its differences are not very profound but appear to be constant; for instance, no leaves of *M. Stokesii* have been found to show the serrations of *M. rapense*. *M. Stokesii* is evidently more distant from the probable ancestor, *M. laetum*, and it seems likely that the ancestral form which populated the Austral Islands and Rapa was very close to *M. rapense* var. *rapense*.

This species is much more variable than *M. rapense*, and some of its forms diverge widely from the norm. *Fosberg 11737* is remarkable for the petalloid appendages which are present on the stamens, but as no other specimen from the island shows this, the plant had better be regarded as a minor variant.

The inconstancy of style pubescence in *M. Stokesii* raises difficulties in separating it from *M. sandwicense;* the forms of *M. Stokesii* with glabrous styles can be positively distinguished from ssp. *Wilderi* only by their narrower leaf shape. The approach of these forms to ssp. *Wilderi* illustrates the difficulty of defining specific lines in the insular myoporums. Even though the distinctions between the Hawaiian and Austral Island species may thus break down, however, the species are in the main distinct, and it would be unwise to combine them before all the insular myoporums have been carefully studied.

Specimens examined

RAIVAVAE:

Form 1. Style copiously hirsutulous.

Near mountain top, alt. 1,000 ft., *Chapin 871* (NY); Pic Rouge, northwest side, alt. 120 m., *St. John & Fosberg 15947* (BISH); same locality, alt. 150 m., *St. John & Fosberg 15956, 15964* (BISH); Maunanui, ridge, alt. 900 ft., *Stokes 11* (BISH); Matotea, alt. 78 m., *Stokes 90* (BISH, type— as to sheet from Raivavae); "Raivavae," *Whitney expedition 237* (NY).

Form 2. Style hirsutulous; stamens with petalloid appendages.

Vaiuru, N. E. slope, alt. 30 m., *Fosberg 11737* (BISH).

Form 3. Style sparsely hirsutulous to glabrous.

South side of Mt. Turivao, rock ledge, alt. 240 m., *Fosberg 11784* (BISH); south side of Mt. Araua, alt. 300 m., *St. John 16201* (BISH);

Pic Rouge, northwest side, alt. 140 m., *St. John & Fosberg 15957* (BISH); Mt. Taraia, south side, alt. 250 m., *St. John & Kondo 15996* (BISH).

11. **Myoporum rapense** F. Brown, Bishop Mus. Bul. 130: 278–279, fig. 42. 1935.

Shrubs or trees, 1–10 m. high. Leaves lanceolate or somewhat obovate, sharply serrate, glabrous, 4–11.5 cm. long, 0.7–2 cm. broad, acute to acuminate, alate-petiolate. Flowers 1–4 (rarely 5) per axil, often 1 or more abortive; pedicels 0.5–1.5 cm. long. Calyx lobes 5, glandular-dotted, lanceolate and acuminate, 2–3.5 mm. long; margins entire, minutely serrulate, or prominently ciliate. Corolla 5-lobed (rarely 6-lobed), white, pink, or purple-spotted in the throat, with a heavy sweet or sometimes fetid odor, 8–12 mm. long, pubescent within. Stamens 4, all well developed or one a rudiment. Ovary 2.5–3.5 mm. long; style hirsutulous, curved at the base, 4–6 mm. long. Drupe brick- or purplish-red; endocarp turbinate or oblong-ellipsoid, not or scarcely ridged, 5–8 mm. long, 3.5–5.5 mm. wide, 3–6-celled (often one or more cells empty).

This species occurs on Tubuai, Raivavae, and Rapa and is more constant morphologically than is its probable derivative *M. Stokesii.* It is separated from this latter species by characters which are very stable for the genus *Myoporum,* and only one specimen is in any way intermediate. The form of *M. rapense* on Raivavae has typical leaves and fruit but flowers more nearly the size of *M. Stokesii.* This form does not seriously break down the boundaries between the two species, however, and it seems best to maintain them as distinct.

While *M. rapense* is clearly separable from *M. Stokesii,* it is not nearly so easily distinguished from the New Zealand *M. laetum.* For the present, however, its more inconspicuously punctate leaves (fully discussed under Morphological Criteria earlier in this paper) may serve to separate it.

12. **Myoporum rapense** var. **rapense**

Pls. I, 15; II, 25, 37; III, 46

Myoporum rapense F. Brown, Bishop Mus. Bul. 130: 278–279, fig. 42. 1935.

Leaves lanceolate or obovate-lanceolate, 4–10 cm. long, 0.7–2 cm. broad. Calyx lobes lanceolate, acuminate, 2–3 mm. long; margins entire or minutely serrulate. Corolla 8–9 (rarely 11–12) mm. long. Ovary 2.5–3 mm. long; style 4–5 (rarely 6) mm. long. Endocarp 5–8 mm. long, 3.5–5.5 mm. broad, 3–6-celled.

TYPE: Rapa, alt. 170 m., Sept. 13, 1921, *Stokes 161*, in the Bishop Museum Herbarium. Brown (1935:279) cited two collections from Rapa as types. I have chosen the first one as the lectotype, since the number of the other (*Stokes 90*) is the same as the type of *M. Stokesii.*

Specimens examined

RAIVAVAE:

This form has a corolla about 12 mm. long, style 6 mm. long.

Vaiuru, 1 km. east, top of beach, alt. 0.5 m., *Fosberg 11723* (BISH).

RAPA:

This form has a corolla 8–9 mm. long, style 4–5 mm. long.

Anarua, alt. 50 ft., *Stokes 161* (BISH, type); Anarua Valley, southeast ridge of Mt. Perahu, alt. 300 m., *Fosberg 11521* (BISH); Matauri Point, near lower edge of forest, alt. 3 m., *Fosberg 11525* (BISH); Anarua Bay, top of beach, alt. 1 m., *St. John 15707* (BISH); Area, alt. 145 m., *St. John & Fosberg 15280* (BISH); Toutore, west of Mt. Vaitau, alt. 240 m., *St. John & Maireau 15409* (BISH); northeast ridge of Mangaoa Peak, alt. 320 m., *St. John & Maireau 15381* (BISH); north slope of Mt. Lekie, mixed woods, alt. 250 m., *St. John & Maireau 15624* (BISH); Karapo Rahi I. [islet off Rapa], alt. 75 m., *St. John & Maireau 15600* (BISH); Taunoa Ridge, alt. 400 ft., *Stokes 90* (as to sheet from Rapa) (BISH); Hiri, north ridge from Lekie, alt. 500 ft., *Stokes 217* (BISH, NY); Kulukulu, Hiri, ridge, alt. 170 ft., *Stokes 304* (BISH).

13. **Myoporum rapense** var. **Skottsbergii** Webster, var. nov.

Pls. I, 14; II, 26

Lobae calicis ciliatae.

Leaves elliptic-lanceolate, 5.5–8 cm. long, 1.2–1.7 cm. broad. Calyx lobes ovate, acuminate-tipped, sparsely long-ciliate on the margins, about 2 mm. long. Corolla 10.5–11 mm. long. Ovary 2.5 mm. long; style 4–4.5 mm. long. Color of flowers and fruits unknown; endocarp 5.5–6 mm. long, with 2 fertile and 2 sterile cells in the one fruit cut open.

TYPE: "Toubouia" [= Tubuai], *Cuming 1430*, in the Kew Herbarium.

This variety is known only from the type collection made by Cuming in 1828. One might explain its not having been collected there again by assuming that the locality given on the label is incorrect, but St. John (1940: 88) has studied Cuming's voyages and cites his collection numbers *1423–1433* as being made on Tubuai. A more likely explanation is that the variety is extinct, inasmuch as St. John and Fosberg did not find it in 1934 after a careful search of the few remaining acres of native forest (personal communication from Dr. St. John).

This variety is named in honor of Dr. Carl Skottsberg, who for many years has been a student of *Myoporum* (and numerous other genera) in the Pacific islands.

DOUBTFUL AND EXCLUDED SPECIES

Myoporum ? euphrasioides Hook. & Arn., Bot. Beechey Voy. 67, 1832.

This plant, described from Whitsunday Island (= Pinaki I., Tuamotus), is now known as *Nesogenes euphrasioides* (Hook. & Arn.) A. DC. Because Hooker and Arnott included the Tuamotus in the Society Islands, a number of writers listed *Myoporum euphrasioides* from the latter group.

Myoporum rimatarense F. Brown, Bishop Mus. Bul. 130: 280, fig. 43. 1935.

This species from Rimatara, Austral Islands, is known from such fragmentary material (the flowers being unknown) that its exact disposition is impossible. Judging from the leaf shape it might be a form of *M. sandwicense* ssp. *Wilderi*, but this is only a guess. St. John tells me that the vegetation on Rimatara is badly despoiled and that the *Myoporum* there may well be extinct.

Myoporum tenuifolium Forst f., Prodr. 44. 1786.

Nadeaud (1897: 113) credits this species to Tahiti (as a cultivated plant) and to Raivavae. The Raivavae plant is probably *M. Stokesii.* The cultivated Tahitian plant may also be *M. Stokesii*, but I have seen no specimens. *M. tenuifolium* is one of the most widespread species of the genus, occurring from New Caledonia into Micronesia, but it has not been collected in Polynesia proper.

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Record of the Shark *Carcharhinus longimanus,* Accompanied by *Naucrates* and *Remora,* from the East-Central Pacific[1]

CARL L. HUBBS[2]

IN THEIR MASTERLY TREATISE on the sharks of the western North Atlantic, Bigelow and Schroeder (1948: 354–364, figs. 64–65), in untangling some complicated synonymies, showed that the pelagic species commonly known as *Carcharhinus lamia* (Risso) cannot bear this name, but should be called *C. longimanus* (Poey). The literature is in such confusion that they were unable to verify the occurrence of this species in any ocean other than the Atlantic. It is therefore gratifying to obtain evidence promptly that it also inhabits the eastern tropical Pacific. This evidence is provided in the form of a photograph of an adult female specimen caught at Lat. 08° 16′ N., Long. 125° 43′ W., by A. J. Carsola and Jeremiah F. Black of the United States Navy Electronics Laboratory, on the ship "Serrano."[3] This picture (Fig. 1) corresponds very closely with Bigelow and Schroeder's figure of an adult female, especially in the highly diagnostic features of the broadly rounded first dorsal fin, the markedly enlarged and round-tipped pectoral fin, the convex posterior border of the lower caudal lobe, the size and position of the anal and second dorsal fins, the extremely short snout in front of the nostrils, and the coloration. There can be virtually no doubt as to the identification.

The lack of previous records from the eastern Pacific (see Beebe and Tee-Van, 1941, and Fowler, 1944) is explicable, for nearly all previous collecting has been near shore, and Bigelow and Schroeder indicate that this species is more strictly pelagic than any other in the Atlantic and is more definitely tropical than most of them. The new Pacific record station lies far off Mexico and east-southeast of the Hawaiian Islands.

The circumstances of the capture of the Pacific specimen are given in the log of the "Serrano," as follows:

> 27 May 1949, 1516 PST. A gray shark with white fin and tail tips was observed swimming around the ship about this time; three fish, each about one foot long and decorated by transverse black and silver stripes maintained formation with the shark, one being about a foot in front of him, another just below his body mid-section and another just above him. The shark was baited with a light hook and line, shot, and pulled onto deck (see picture).

The banded fish were of course *Naucrates ductor* (Linnaeus). Like the *Carcharhinus* that they were accompanying, the pilotfish are referable to a circumtropical species. It is true that Fowler (1905: 62–65, fig. 3) described the Pacific form as a distinct species, *Naucrates polysarcus*, partly on the basis of differences pointed out by Gill (1862: 440–441), but it now seems likely that the distinction was based on juvenile characters. The supposedly deeper body and the longer fins may well be characters of the young. Meek and Hildebrand (1925: 401) stated that "the

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[1] Contributions from the Scripps Institution of Oceanography, New Series, No. 493. Manuscript received February 1, 1950.

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[3] Thanks are due E. R. Anderson of the United States Navy Electronics Laboratory for the transmission of data, photograph, and specimen.

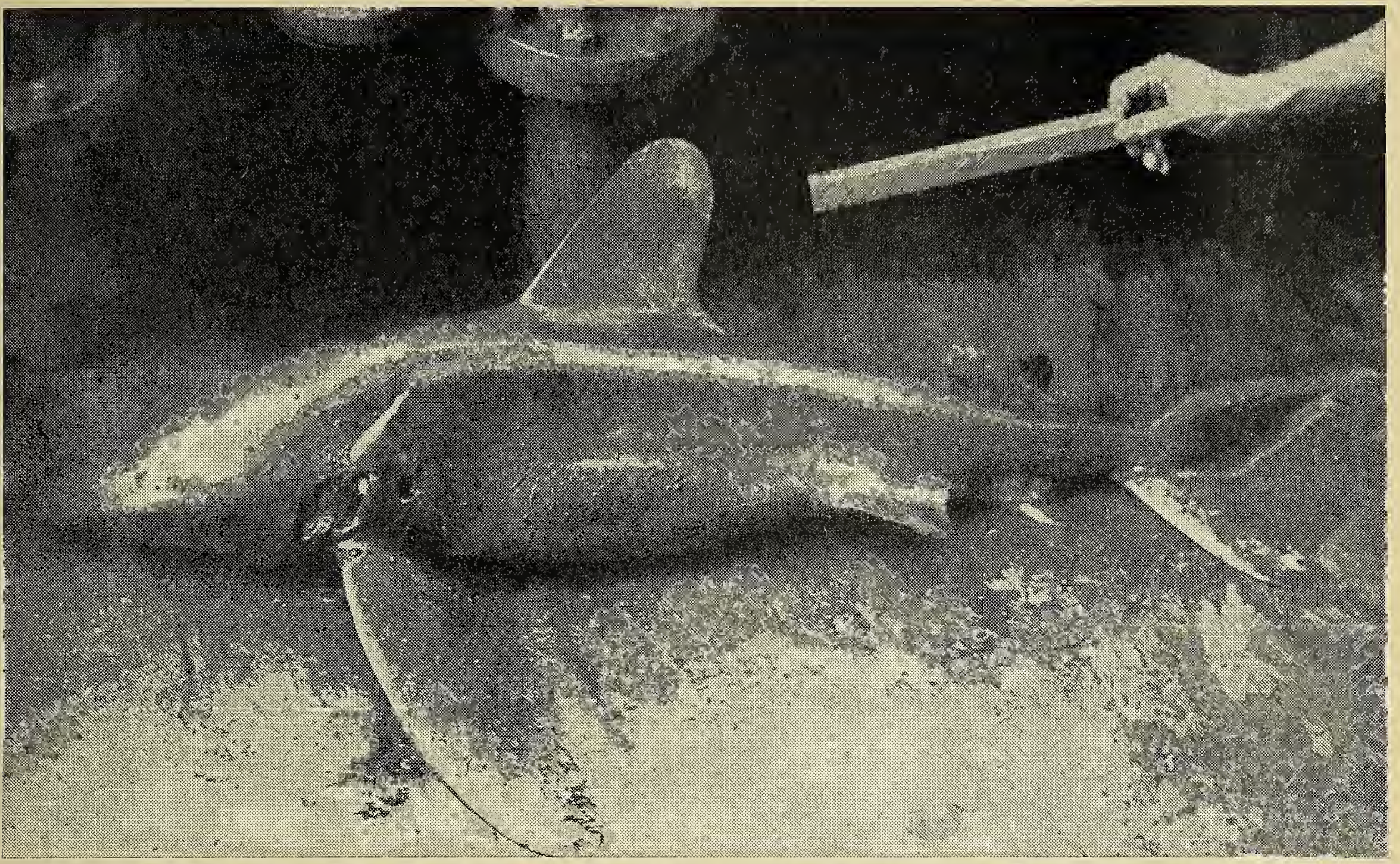

Fig. 1. Adult female of *Carcharhinus longimanus* (Poey), from the east-central Pacific. OFFICIAL PHOTOGRAPH, U. S. NAVY.

young appear to be deeper and more strongly compressed than the adult"; Wakiya (1924: 232, pl. 38, fig. 2), however, indicated that the young of "*Naucrates indicus*" are more slender than the adult. The original figure of *N. polysarcus* suggests that the extreme depth ascribed to the type may be attributed to its poor preservation. The different scale count, also emphasized by Fowler, is probably not significant, for the scales are too irregularly arranged to be counted precisely. Jordan and Starks (1907: 72) found that the supposed characters do not hold for a Pacific species, and Meek and Hildebrand, though failing to include *polysarcus* in their synonymy, refer Pacific material to *N. ductor*. Walford (1937: 66–68) likewise referred the Pacific form to *N. ductor* (and by mistake labeled the figure, which was taken from Jordan and Evermann, as "from Jordan and McGregor, 1898"). An adult specimen 325 mm. in standard length, recently received from off the Pacific coast of Mexico, has the slender form and the short fins ascribed by Fowler to the Atlantic form. Recently, Fowler (1944: 423, 500) treated *polysarcus* as a subspecies of *ductor*.

From the shark there was taken a specimen, 105 mm. long, of another circumtropical species, *Remora remora* (Linnaeus). It agrees satisfactorily with material from southern California.

The specific integrity of such circumtropical pelagic fishes poses a problem in speciation, since widespread littoral types of the tropics, as well as most pantemperate types, in contrast, are ordinarily differentiated into allopatric subspecies or species, though their period of isolation has ordinarily been no longer, often briefer, than that of the land-separated populations of the tropical pelagic forms. The explanation seems to lie both in the uniformity of the tropical pelagic environment and in the relationship between the population structure and the rate of speciation. Large, widespread populations that are not disrupted into effective reproductive units are now generally held, on the basis of Wright's analyses (1940*a*, *b;* 1942), to be little subject to differentiation.

ADDENDUM

After this manuscript was submitted for publication, Springer (1950: 2, 7–8) erected a distinct genus, *Pterolamia*, for the reception of *Carcharhinus longimanus* and, probably also, of *C. insularum* (Snyder), a species described from the Hawaiian Islands. He separated this nominal genus from *Eulamia* solely on the basis of the rounded tips of the dorsal and pectoral fins. Since the sharpness of these fins varies considerably and since the rounded tips seem to involve merely the retention of an embryonic feature, I am disinclined to accept the generic separation. Some other species of *Carcharhinus*, for example, *C. falciformis* (Müller and Henle) as described by Bigelow and Schroeder (1948: 329–333, figs. 56–57), have the pectoral scarcely more pointed than in *C. longimanus* and have the dorsal distinctly though less broadly rounded. Nor does Springer's separation of *Eulamia* from *Carcharhinus* seem justified on the basis of the presence or absence of a middorsal ridge—a very tenuous distinction that depends in large part on the condition of preservation and that seems to be inconsistent, in some species at least.

That *Carcharhinus longimanus* may be common in the open equatorial Pacific is suggested by a picture in the recently published book *Kon-Tiki*, showing nine sharks caught in one day (Heyerdahl, 1950: lower figure of 2d pl. following p. 176; accompanying text apparently on pp. 205–206). So far as is obvious all sharks in this picture seem referable to the pelagic species under discussion. This identification is ventured on the basis of the showing of certain diagnostic characters, in particular the broadly rounded pectoral fins, much longer than the head; the far-forward position of the nostrils on the very short, strongly rounded, laterally angulated snout; and the plain coloration. The location of the catch is not specified, but the context indicates that it was in the South Equatorial Current somewhere between Perú and the Tuamotu Archipelago.

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Common and Aberrant Flowers of *Cassia fistula*

MARIE C. NEAL[1]

WHILE COLLECTING HERBARIUM SPECIMENS from golden shower trees (*Cassia fistula* L., a legume from India) at my home in Nuuanu Valley, Honolulu, I noticed that three of our four trees (A, C, D) bore the common form of flowers and that a fourth (B) bore aberrant forms. This discovery led to the examination of other trees of the same species. After studying from June to September, 1948, four or more flowers of each of 26 trees of *C. fistula* in seven different localities in Honolulu, I found that trees A, C, and D definitely bore the common form of flowers, which were nearly uniform. Only tree B bore flowers deviating distinctly from those borne by the other trees. Examination of all these flowers and also of literature dealing with *C. fistula* led to two conclusions: (1) The stamens of the common form of *C. fistula* needed redescription; and (2) the petals, sepals, and stamens of the aberrant form of *C. fistula* differed in several ways from those of the common form.

COMMON FLOWERS

The common form of the flower of *C. fistula* has 5 petals, 5 sepals, and 10 stamens, and it has been described many times. Wight (1840, pl. 269) has a figure which more or less epitomizes these descriptions and from which is here reproduced a detail (Fig. 1), showing flowers for comparison with my drawing (Fig. 2). In Wight's figure, the three shortest stamens appear to be alike. The petals and sepals of published descriptions seemingly were like those of flowers on 25 of the trees examined by me. The stamens, however, were different. As seen in a diagram of the receptacle (Fig. 3), the 10 stamens are actually arranged in two series, the five inner ones being opposite the five petals, the five outer ones being opposite the five sepals. The five inner stamens, Nos. 2, 4, 6, 8, 10 (Fig. 2, *A, B;* Fig. 4, *A–D*), have rather short filaments and versatile, two-celled, slightly compressed, curving-obovoid anthers, each cell opening by a basal pore. No. 2, the uppermost stamen,

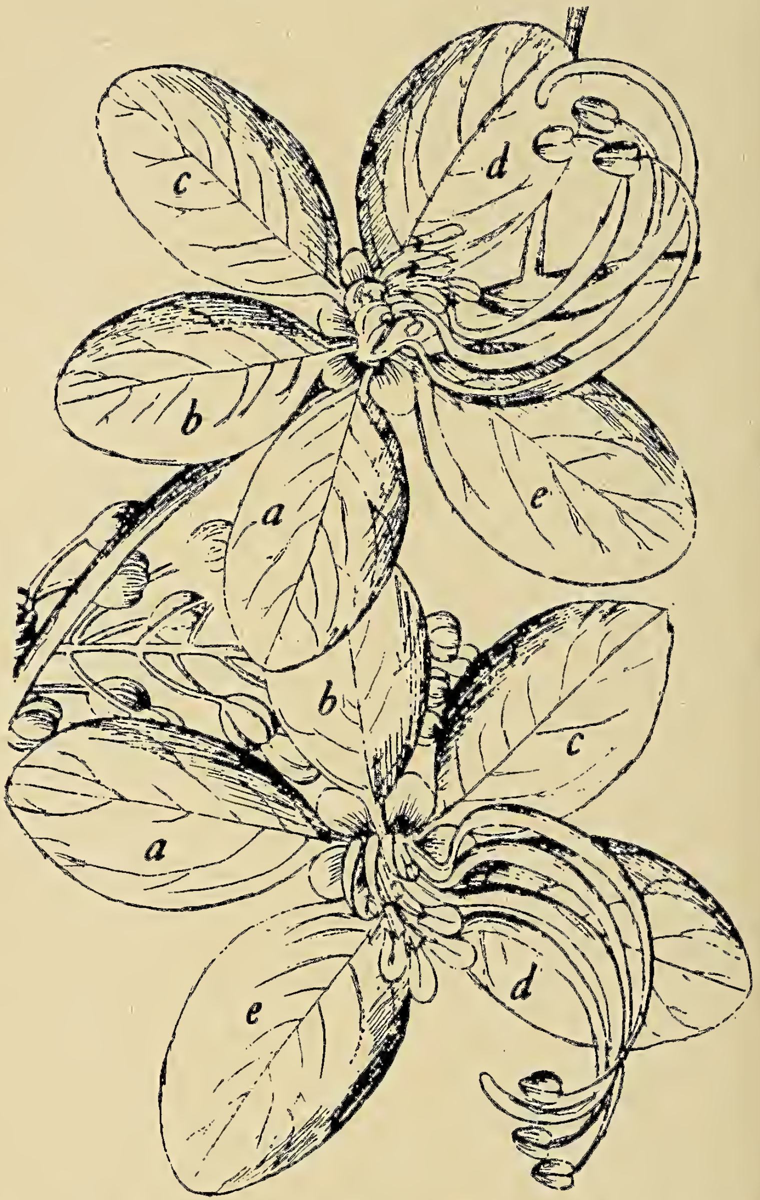

FIG. 1. Flowers of *Cassia fistula*, reproduced from Wight's plate; letters added to petals to agree with Figure 2.

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[1] Botanist, Bernice P. Bishop Museum, Honolulu, T. H. Manuscript received April 6, 1950.

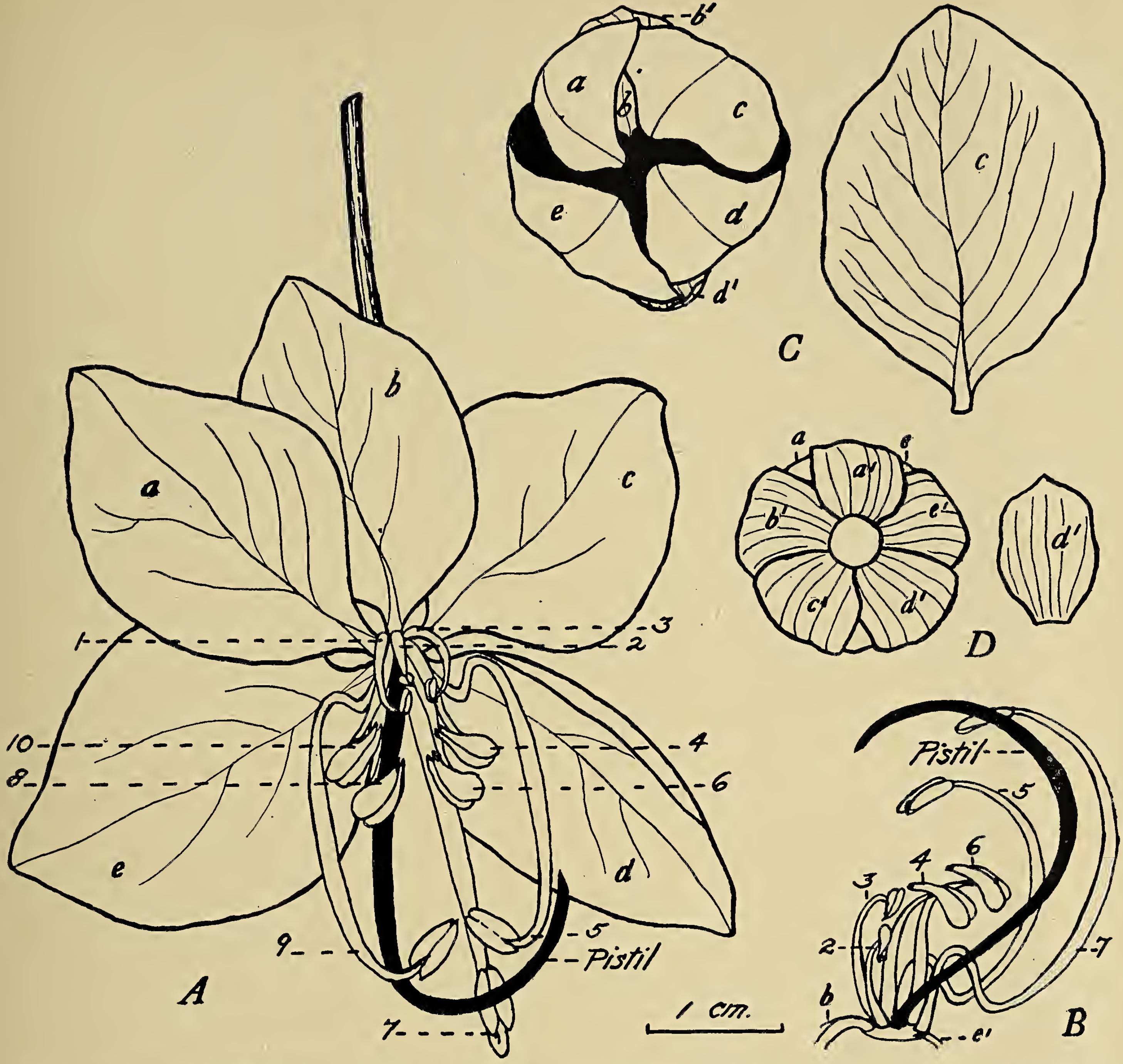

FIG. 2. Flower of *Cassia fistula* from tree C. *A*, Front view: *a–e*, petals; 1, 3, 5, 7, 9, outer, fertile stamens; 2, 4, 6, 8, 10, inner, sterile, starch-bearing stamens. *B*, Arrangement of stamens on right side of flower. *C*, Bud, front view: *a–e*, petals; *c*, single petal. *D*, Bud, back view: *a'–e'*, sepals; *d'*, single sepal.

has the shortest filament and (with Nos. 1 and 3) the smallest anther, and it faces Nos. 4, 6, 8, and 10. Nos. 4 and 10 are paired and are borne on longer filaments than No. 2. Nos. 6 and 8 are paired and are borne on slightly longer filaments than Nos. 4 and 10. All five of these stamens yield pollen.

The five outer stamens, Nos. 1, 3, 5, 7, 9 (Fig. 2, *A*, *B;* Fig. 4, *E–H*), have two-celled, compressed, ovoid anthers, each cell opening by an interrupted longitudinal cleft. Two of these stamens, the upper ones (Nos. 1 and 3), are paired and have short, twisted filaments, little longer than the filament of No. 2, and small, versatile anthers about the size of the anther of No. 2. The other three, lower stamens (Nos. 5, 7, 9), are similar to one another. They have the longest filaments, which curve outward after making a short backward bend at the base, and they bear at their distant tips anthers tending to be slightly smaller than those of Nos. 4, 6, 8, and 10; and though they are not basifixed they are not versatile, but continue in a line with their filaments. All five of these stamens yield pollen.

My description of the 10 stamens does not agree entirely with any I have found in botanical literature. Taubert (1891: 158) states in a summary of subgenera of *Cassia* that sub-

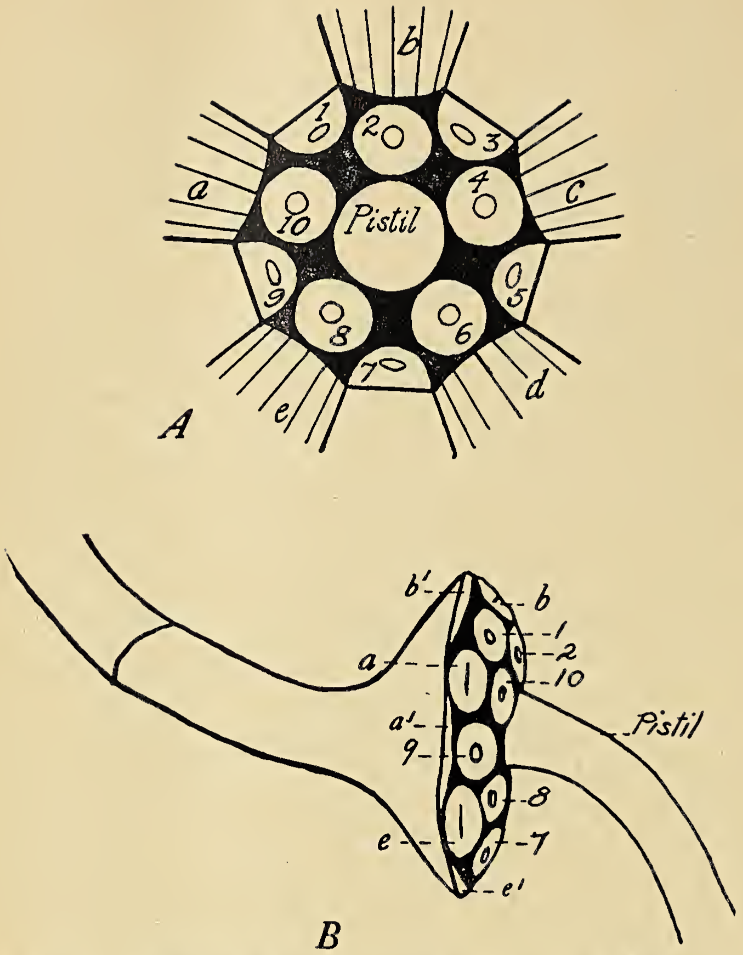

FIG. 3. Receptacle of common form of flower of *Cassia fistula*. *A*, Diagram, front view, showing points of attachment of stamens (1–10) in relation to petals (*a–e*) and pistil. *B*, Side view, showing also points of attachment of sepals *a'*, *b'*, *e'*.

genus *Fistula*, to which *C. fistula* belongs, has the three lower stamens (my Nos. 5, 7, 9) with long, bent filaments, and with anthers opening by longitudinal clefts; the seven upper stamens with short filaments and with anthers opening by basal pores; the anthers of the one to three uppermost stamens (my Nos. 1, 2, 3) sometimes abortive. This description of the stamens of *C. fistula* or the subgenus *Fistula* is the description commonly found, the majority of opinions being that the three smallest stamens (my Nos. 1, 2, 3) were alike and without pollen (and, according to some authorities, indehiscent); that the arrangement was seven (or four) anthers with basal pores and the three on long filaments with longitudinal clefts.

Examples of descriptions of the stamens of *C. fistula* follow:—Bentham and Hooker (1865: 572): "Stamina perfecta 10, filamentis 3 inferioribus elongatis, antheris saepius oblongis breviter 2-rimosis, 7 superioribus abbreviatis antheris minute 2-porosis." Trimen (1894: 103, 104): "3 lowest stam. with very long doubly curved exserted fil. and oblong anth. dehiscing longitudinally, 4 lat. ones with short straight fil. and versatile anth. opening by pores at the base, 3 uppermost ones much smaller, erect, with indehiscent abortive anth." Brandis (1907: 253): "The three lower stamens have long curved filaments and anthers, which open by longitudinal slits, four stamens have short filaments and anthers opening by basal pores; the rest have minute anthers without pollen." Rock (1920: 75): "Three stamens with long filaments, 7 stamens with short filaments, anthers of three basifixed opening in longitudinal slits, anthers of seven dorsifixed opening in basilar pores."

As seen by my diagrams and descriptions, the arrangement is of five stamens of each of two kinds in two series, one series opposite the petals, the other opposite the sepals. I have examined the pollen of the "abortive" stamens (Nos. 1, 2, 3) and found apparently normal grains, some slightly smaller than some of those of No. 8, for example, which, however, were turgid with starch. Some of the grains of Nos. 1, 2, 3, also, were slightly smaller than those of Nos. 5, 7, 9, even after the starch contents of Nos. 5, 7, 9 had evidently been converted in mature flowers from starch by diastase (Tischler, 1910: 241). Grains of Nos. 1, 2, 3, from flowers at different stages of development, were tested for starch and dextrin (with iodine dissolved in potassium iodide) and were found to contain varying amounts of both. Thus it seems probable that the small stamens do function—Nos. 1 and 3 like Nos. 5, 7, 9, No. 2 like Nos. 4, 6, 8, 10.

Tischler (1910: 220) agreed with Knuth (1904: 375–377) in Knuth's description of the stamens of *C. fistula*, which is translated as follows (Knuth had studied the flower ecology of *C. fistula* in Buitenzorg):

Cassia fistula has three abortive stamens; these have anthers to 2 mm. long, which are bent inward and are borne on filaments to 10 mm. long. Because of their nature and position they serve chiefly as footholds for the wood bee. Next to them are the four starch-bearing, sterile stamens with filaments 10 mm. long and anthers 5 mm. long. Three fertile stamens arise from the flower's base, the filament basally being directed upward, then after 5 mm. suddenly turning backward, and finally bending in a large curve out of the flower, so that the 5×2 mm. anthers are to 25 mm. from the flower base.

Tischler states that he has nothing to add to this description and that like Knuth he saw the pollinating wood bee "milk" the starch-bearing anthers (my Nos. 4, 6, 8, 10) for food and get pollinated by the fertile anthers (my Nos. 5, 7, 9), the pollen of which it then carried to stigmas of other flowers.

The position of the style may be between stamens Nos. 5 and 7 or between Nos. 7 and 9.

ABERRANT FLOWERS

The cause of the aberrations in tree B is not known. The four trees in our garden, A, B, C, D, are about 12 years old. The 22 other trees examined are probably older. The general aspect of tree B is like that of the common form of *C. fistula*. But the leaves are slightly shorter and the leaflets smaller than those of A, C, D; none, however, was malformed. According to Ridgway's Color Chart, the "wax yellow" flowers of tree B are a duller yellow than the "lemon chrome" flowers of tree A, for example; this comparison, on being analyzed, shows that the flowers of both B and A have the same hue, orange-yellow-yellow (25 per cent orange, 75 per cent yellow), but that "wax yellow" is grayer, a stage nearer neutral. Besides other differences of the flowers, some racemes though at first as large soon become small and rounded, with flowers clustered at the tip only, instead of remaining long and more or less obconical, as in the common form; other racemes are small and rounded from the beginning. The seeds look like those of tree A, for example; but the pods are far fewer, some are shorter, and others have constrictions.

All these slight differences might well be within the range of the species. Hybridism does not explain the differences, since the regular shaped sepals, petals, and stamens found among the irregular shaped ones of tree B were much like those of the common form of flower of trees A, C, and D.

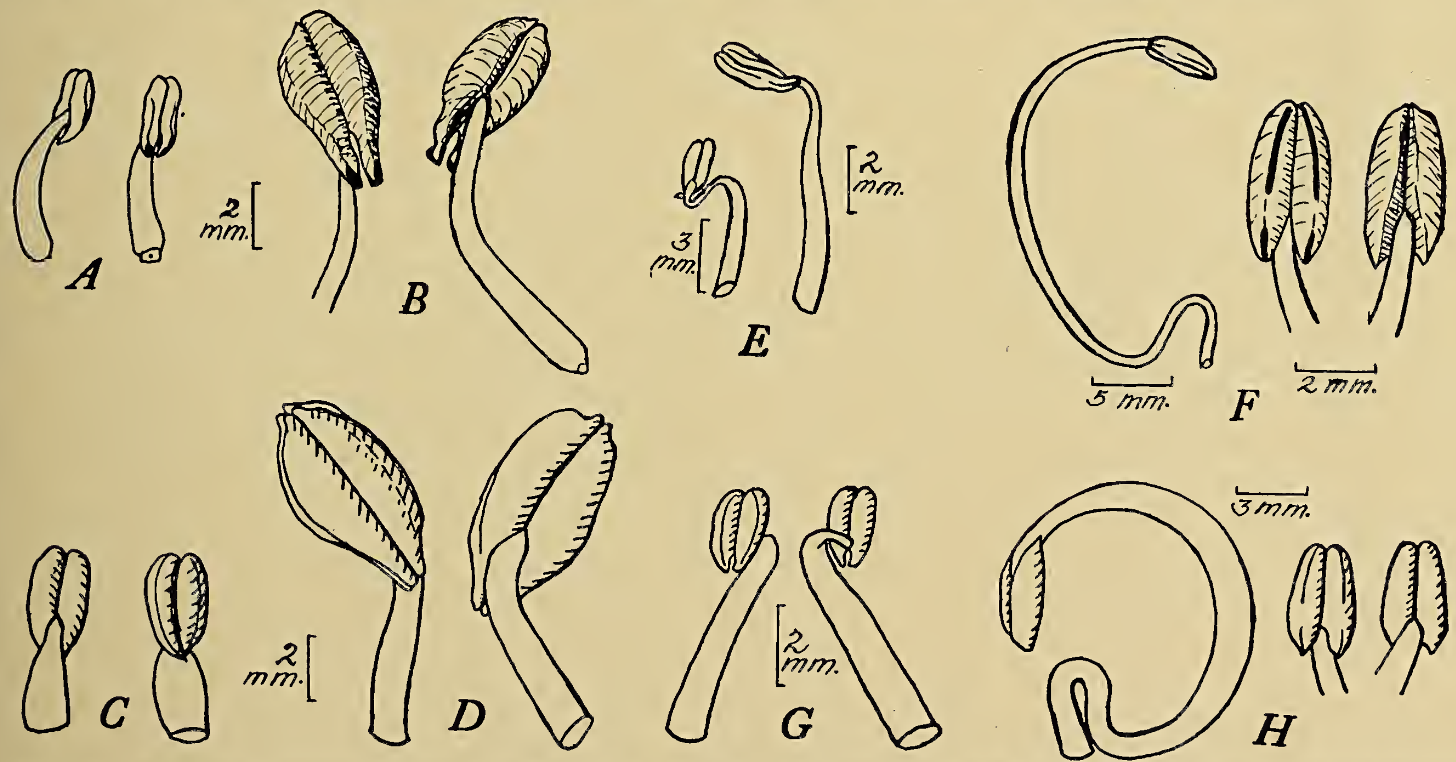

Fig. 4. Stamens of common form of flower of *Cassia fistula*, front and back views. Upper row: mature stamens from open flower, anther cells open. Lower row: stamens from bud, anther cells not open. *A* and *C*, No. 2; *B* and *D*, No. 8; *E* and *G*, No. 1 (*E* shows No. 1 from two different flowers); *F* and *H*, No. 9.

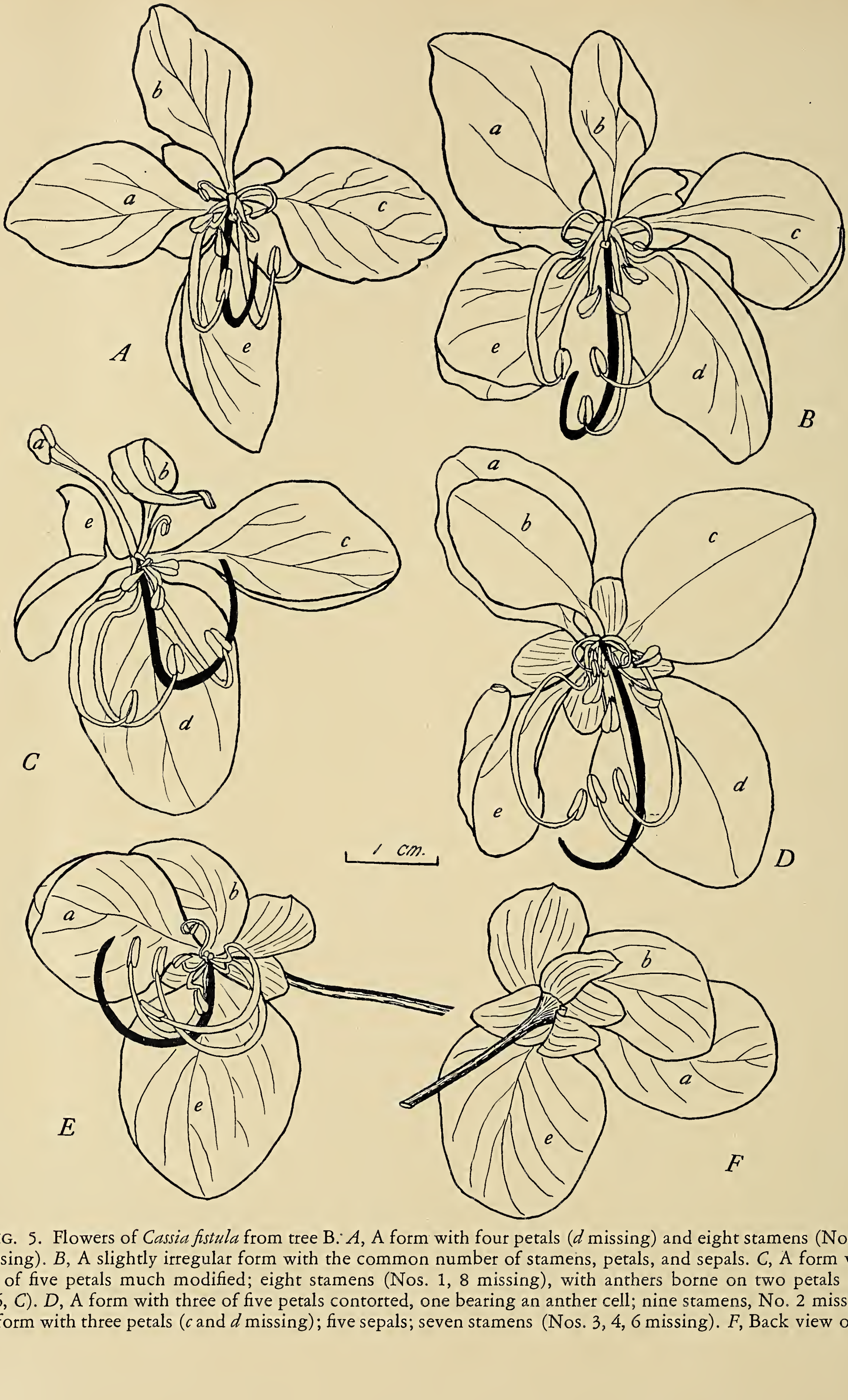

FIG. 5. Flowers of *Cassia fistula* from tree B: *A*, A form with four petals (*d* missing) and eight stamens (Nos. 6, 7 missing). *B*, A slightly irregular form with the common number of stamens, petals, and sepals. *C*, A form with three of five petals much modified; eight stamens (Nos. 1, 8 missing), with anthers borne on two petals (see Fig. 6, *C*). *D*, A form with three of five petals contorted, one bearing an anther cell; nine stamens, No. 2 missing. *E*, A form with three petals (*c* and *d* missing); five sepals; seven stamens (Nos. 3, 4, 6 missing). *F*, Back view of *E*.

The possibility that 2,4–D was the cause has been suggested. For 2 or 3 years before this study was made, trees A and B were exposed to 2,4–D, which was applied in solution from a watering pot on the ground near their trunks in order to rid that part of the lawn of pennywort and other weeds. This treatment did not seem to affect tree A. In July, 1949, a year later, and without another application of 2,4–D, tree B again bore aberrant flower forms. The effect of this hormone-like substance on herbs is temporary and comparatively short (Zimmerman, 1943); but the effect appears later and lasts longer on woody plants. Applications of 2,4–D to weeds along a fence of living hau (*Hibiscus tiliaceus* L.), at Kailua, Oahu, caused malformed leaves on the hau more than 6 months later;[2] flowers, being absent, were not studied. According to Zimmerman (1943), modified organs may well be caused by an environment (or chemicals) which permits different potentialities of the protoplasm to develop, inasmuch as "the so-called 'normal' characters of a plant are but a partial expression of the range of possibilities of which the protoplasm is capable."

Although I had not examined the flowers of tree B in detail until June, 1948, for years before then I had noticed the general appearance of the tree with its small, rounded racemes, and I believe it always has been different. In fact, it may be a sport. If so, this would also explain the comparatively small number of pods, which is characteristic of a sport and is not usually caused by 2,4–D (van Overbeek, 1946). Nonetheless it is possible that fasciation found on tree B in July, 1949, might have been caused by the application of 2,4–D the year before. The tree bore many more flowers in 1949 than in 1948, and among them were found four racemes with conspicuously flattened peduncles and rachises. No fasciation was noticed in 1948.

The striking difference in tree B is in the strange flowers. These vary in the same raceme, and they follow several patterns. One common form of flower on tree B had four petals, four sepals, eight stamens (Fig. 5, *A*). Another form had five petals, three of which were more or less irregular, four or five sepals, and eight to 10 stamens (Fig. 5, *B*, *C*, *D*). A third form had three petals, four or five sepals, and seven or eight stamens (Fig. 5, *E*, *F*).

The pistils were not noticed to differ from those of the common form.

The sepals were not all equal in size and some seemed to function as petals, one being large, rounded, and yellow (instead of green) where a petal was missing (Fig. 5, *E*, *F*). One or both of the innermost sepals (Fig. 2, *D*, *b′*, *e′*) seemed often to be petal-like. Although flowers on some of the 25 other trees examined were often found to have one or both of the inner sepals more or less petal-like, none reached the size of those on tree B.

The petals varied greatly in size and shape, from round to narrow and more or less curved. Some petals combined with filaments or substituted for them and bore anthers.

The stamens were very variable, both as to filaments and anthers. In extreme examples two anthers might combine, those studied combining an odd and even type anther, such as Nos. 3 and 4, with No. 3 at the tip (Fig. 6, *G*). The presence of an anther with either one or two cells on the edge of a petal was common. The anther was always found to be like the anther of stamens Nos. 1, 3, 5, 7, or 9 (Fig. 4, *E–H*), that is, the outer series of stamens opposite the sepals; and its pollen grains contained starch. Nos. 1 and 3 seemed more commonly malformed than 5, 7, or 9. The calloused edge of the petal from its base to the anther suggested a reduced filament. A calloused edge might end bluntly with a vestigial anther or none. A filament might be edged or tipped with yellow petal material. Some of these aberrations are illustrated (Fig. 6, *A–G*). The stamens and petals and the petals and sepals were partly interfunctional. But the stamens and sepals were not. This closer relationship between petals and sta-

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[2] Personal communication from A. J. Mangelsdorf, 1949.

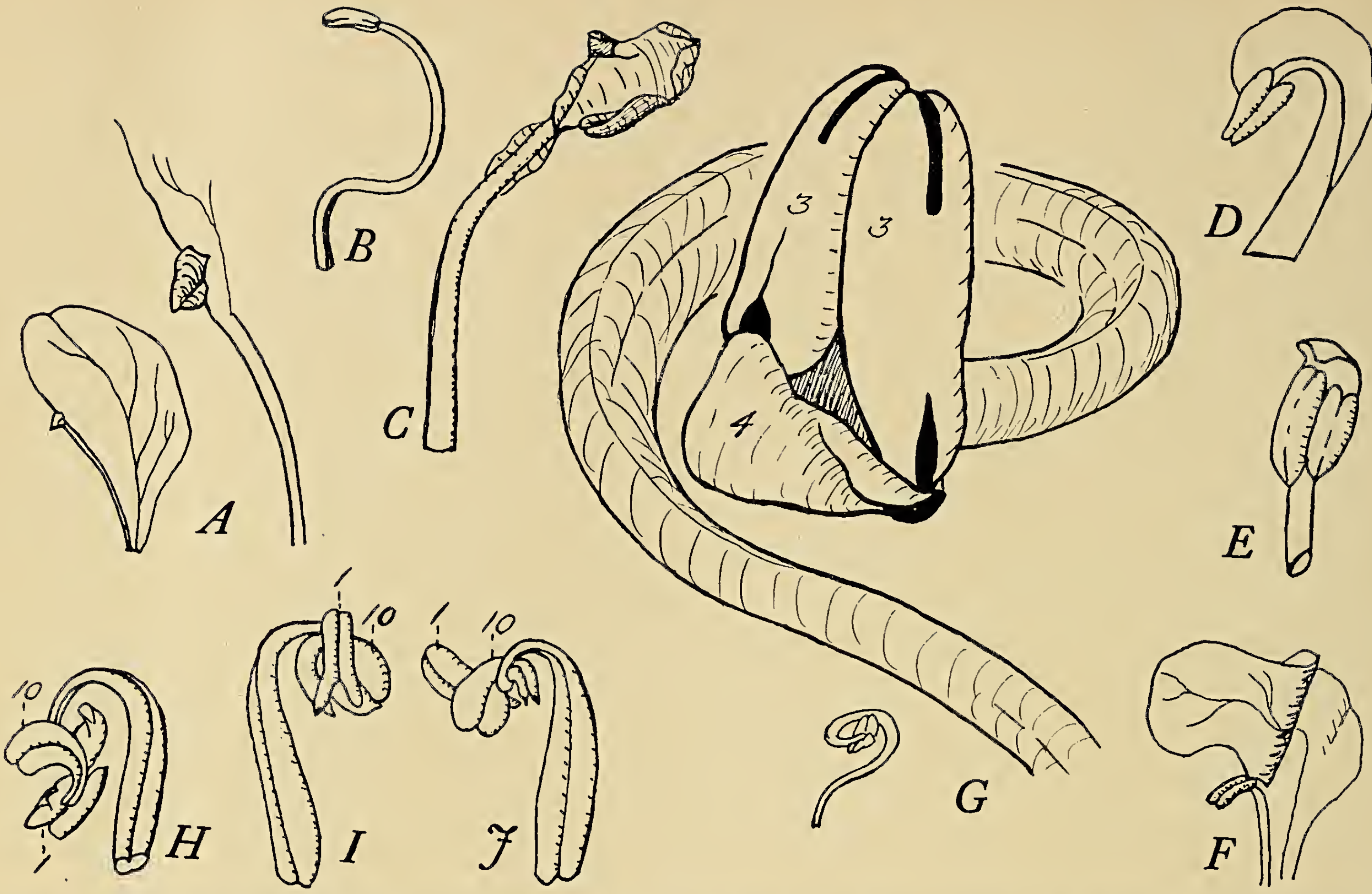

FIG. 6. Peculiar stamens and combinations of reduced stamens and petals in flowers of *Cassia fistula*: tree B (*A–G*), tree H (*H–J*). *A*, Reduced anther in five-petaled flower with eight stamens and four sepals. *B*, Stamen No. 1 imitating missing No. 9 but smaller. *C*, Stamen No. 1 on petal *a* (see Fig. 5, *C*). *D*, Stamen No. 3 on petal *c* (Nos. 7, 8, 9, and petal *b* missing). *E*, Stamen No. 7 on petal *e* (Nos. 1 and 9 missing, one of five petals, *e*, reduced). *F*, Stamen No. 1 on petal *b* (Nos. 9, 10, and petal *e* missing). *G*, Double stamen, Nos. 3 and 4 (Nos. 7, 8, and petal *d* missing). *H, I, J*, Three views of a double stamen, Nos. 1 and 10.

mens is confirmed by observations of plant anatomists, as by Eames (1931: 170), who, in figures of flowers, shows that vascular bundles of sepals, petals, and stamens may be united within the flower but that the bundles of the sepals may branch off much farther down than do those of the petals and stamens. Other instances of stamens being borne on petals or functioning as petals are sometimes found, as in double roses, double hibiscus, peonies, and water lilies. Many flowers having both calyx and corolla, as the mints and verbenas, bear stamens on the corolla tubes. In representatives of the ginger, canna, and maranta families, most of the stamens are sterile, conspicuous, and petal-like.

Among the 26 trees of *C. fistula* examined, two other oddities were found. On two trees, H and I, both near Bishop Museum, two aberrant forms of flowers were found. From tree I, five flowers were taken, four of which were of the common five-parted form. The other had the same arrangement, but six petals, six sepals, and 12 stamens (one extra of each of No. 5 and 6 forms). From tree H, nine flowers were taken. One flower was five-parted but aberrant in having stamens Nos. 4, 10, 6, and 8 not paired but of different lengths, No. 4 being the shortest, No. 10 a little longer, No. 6 longer, and No. 8 longest. Seven flowers were five-parted except that they had only nine stamens, the missing stamen being No. 4 or No. 10. With No. 4 missing, the base of petal *c* came to a point between stamens Nos. 3 and 5, which therefore stood close together. The ninth flower was five-parted throughout, but stamens Nos. 10 and 1 were joined, having a double filament and the anther of No. 1 standing just above the anther of No. 10 (Fig. 6, *H–J*). Some other flowers of tree H were examined and found to be the common five-parted form.

CONCLUSIONS

Conclusions concerning the common form of flower of *C. fistula:* The 10 stamens are arranged in two series. The five inner stamens are opposite the five petals. They have similar filaments and similar basiventral anthers, but one stamen is much smaller than the others. The five outer stamens are opposite the five sepals. They have similar anthers, which open by clefts; but two have smaller anthers and shorter filaments than the other three. The three so-called "abortive" stamens contain and discharge pollen as do the seven larger stamens.

Conclusions concerning the aberrant forms of flowers of *C. fistula* on tree B are that three forms which are irregularly three-, four-, or five-parted seem to dominate. Stamens and petals are more or less interfunctional, as also are sepals and petals, but not stamens and sepals. Inasmuch as all flowers examined on tree B deviated from the common form of the species, this tree may be a sport. It is possible that 2,4–D caused the fasciation in peduncles and rachises found in some inflorescences, but it is not likely that it caused the odd flower forms. It seems improbable that 2,4–D caused reduction in the size of the leaves, which were not malformed. Among the other trees examined, irregular flower forms may develop; but they are rare and not the rule.

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A Survey of the Lace-necked Dove in Hawaii

Charles W. Schwartz and Elizabeth Reeder Schwartz[1]

Streptopelia chinensis chinensis (Scopoli), popularly called the Lace-necked or Spotted Dove because of its characteristic feather pattern, is a common member of the introduced avifauna of the Hawaiian Islands. No information is available concerning the date or exact source of its importation from eastern China to Hawaii, but this dove was very common on Oahu in 1879 (Caum, 1933) and had become established on the other major islands sometime prior to 1900 according to long-time residents interviewed during this survey.

Lace-necked Doves are now permanent residents on all the major Hawaiian Islands. Kahoolawe, a 45-square-mile bombing target under military jurisdiction and 6½ miles offshore from Maui, was not visited during this survey but it is likely that Lace-necked Doves live there. No personal observations were made on Niihau, but the owners of this 72-square-mile island reported in conversation that Lace-necked Doves were well established there and this report has been confirmed by Fisher (MS). The Lace-necked Dove has been observed to fly between the islands of Niihau and Kauai, a distance of 18 miles, and it is conceivable that this species may have voluntarily established itself on the major islands other than Oahu, the probable site of original planting. If this is so, the greatest flight over open water would have occurred between Oahu and Kauai, a distance of 73 miles. The alternative of transportation from one island to another by humans is likewise plausible.

DISTRIBUTION AND POPULATION

Climatic conditions and the vegetative pattern define the limits of the range of the Lace-necked Dove in the Hawaiian Islands and influence the use of a given area and its population density. The range of this species occurs mostly from sea level to 4,000 feet elevation (Fig. 2), where mean annual temperatures grade from 75° F. at the lowest elevation to 60° F. at the highest elevation; however, in one area on Hawaii it reaches 8,000 feet, where the mean annual temperature is estimated to be around 40° F. Depending on the locality, rainfall in the Hawaiian range of this species varies from less than 10 inches up to a maximum of 250 inches annually. Lace-necked Doves are found in pineapple and sugar cane plantations, in pastures and waste lands, in small truck gardens, homesteads, and urban areas, and in openings of forested sections; dense forests and barren lava are uninhabited.

In order to evaluate this distribution and the abundance of Lace-necked Doves, we have employed the classification of *Vegetation Zones of Hawaii* (Ripperton and Hosaka, 1942), which correlates climatic conditions, the vegetation pattern, and land use throughout Hawaii. While these zones are referred to here, their descriptions and maps are not repeated because of summaries in two other publications (Schwartz and Schwartz, 1949 and 1950).

Range, populations, and densities of the Lace-necked Dove are given according to vegetation zone in Table 1. Strip counts were made in all occupied range and formed the basis for densities representing daytime dis-

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TABLE 1

DISTRIBUTION AND POPULATIONS OF THE LACE-NECKED DOVE IN HAWAII BY VEGETATION ZONE

VEGETATION ZONES	SQUARE MILES	SQUARE MILES OCCUPIED	PERCENTAGE OF ZONE OCCUPIED	TOTAL POPULATION	SQUARE MILES WITH DENSITIES OF				
					1–10	11–25	26–50	51–100	101–200
ZONE A									
Hawaii....	249	232	94	3,920	82	111	39	0	0
Kauai.....	23	23	100	1,150	0	0	23	0	0
Lanai......	72	72	100	630	66	0	6	0	0
Maui......	121	97	80	5,160	3	0	77	17	0
Molokai...	64	64	100	5,060	0	24	0	33	7
Oahu......	67	51*	76	1,020	0	51	0	0	0
Total....	596	539	90	16,940	151	186	145	50	7
ZONE B									
Hawaii....	408	397	97	11,090	169	63	165	0	0
Kauai.....	116	113	97	3,850	0	60	53	0	0
Lanai......	57	57	100	2,440	23	0	13	21	0
Maui......	138	78	56	4,250	0	0	65	13	0
Molokai...	74	74	100	4,200	0	32	12	25	5
Oahu......	169	137†	82	3,840	0	117	0	20	0
Total....	962	856	89	29,670	192	272	308	79	5
ZONE C_1									
Hawaii....	194	183	94	2,940	96	79	8	0	0
Kauai.....	88	78	89	3,200	8	13	57	0	0
Lanai......	10	9	90	400	4	0	2	3	0
Maui......	54	37	68	1,710	0	5	32	0	0
Molokai...	46	44	96	4,330	0	9	0	28	7
Oahu.....	146	132	90	3,550	0	106	13	13	0
Total....	538	483	90	16,130	108	212	112	44	7
ZONE C_2									
Hawaii....	316	196	62	5,740	70	42	84	0	0
Kauai.....	11	10	91	190	1	9	0	0	0
Lanai......	0	0	0	0	0	0	0	0	0
Maui......	61	34	56	2,550	0	0	0	34	0
Molokai...	0	0	0	0	0	0	0	0	0
Oahu......	0	0	0	0	0	0	0	0	0
Total....	388	240	62	8,480	71	51	84	34	0
ZONE D_1									
Hawaii....	464	417	90	4,880	346	71	0	0	0
Kauai.....	113	73	65	1,950	2	54	17	0	0
Lanai......	2	0	0	0	0	0	0	0	0
Maui......	97	69	71	2,810	16	0	53	0	0
Molokai...	32	2	6	400	0	0	0	0	2
Oahu......	110	101	92	3,440	0	54	29	18	0
Total....	818	662	81	13,480	364	179	99	18	2
ZONE D_2									
Hawaii....	790	104	13	1,040	104	0	0	0	0
Kauai.....	194	0	0	0	0	0	0	0	0
Lanai......	0	0	0	0	0	0	0	0	0
Maui......	151	5	3	250	0	0	5	0	0
Molokai...	44	0	0	0	0	0	0	0	0
Oahu......	112	30	27	600	0	30	0	0	0
Total....	1,291	139	11	1,890	104	30	5	0	0

*Sixteen square miles of urban area occupied by Lace-necked Doves not censused.

†Thirty-two square miles of urban area occupied by Lace-necked Doves not censused.

TABLE 1 (Continued)

DISTRIBUTION AND POPULATIONS OF THE LACE-NECKED DOVE IN HAWAII BY VEGETATION ZONE

VEGETATION ZONES	SQUARE MILES	SQUARE MILES OCCUPIED	PERCENTAGE OF ZONE OCCUPIED	TOTAL POPULATION	SQUARE MILES WITH DENSITIES OF				
					1–10	11–25	26–50	51–100	101–200
ZONE D_3									
Hawaii....	353	74	21	740	74	0	0	0	0
Kauai.....	10	9	90	130	4	5	0	0	0
Lanai......	0	0	0	0	0	0	0	0	0
Maui......	23	0	0	0	0	0	0	0	0
Molokai...	0	0	0	0	0	0	0	0	0
Oahu......	0	0	0	0	0	0	0	0	0
Total....	386	83	21	870	78	5	0	0	0
ZONE E_1									
Hawaii....	647	92	14	940	90	2	0	0	0
Kauai.....	0	0	0	0	0	0	0	0	0
Lanai......	0	0	0	0	0	0	0	0	0
Maui......	39	0	0	0	0	0	0	0	0
Molokai...	0	0	0	0	0	0	0	0	0
Oahu......	0	0	0	0	0	0	0	0	0
Total....	686	92	13	940	90	2	0	0	0
ZONE E_2									
Hawaii....	503	28	5	280	28	0	0	0	0
Kauai.....	0	0	0	0	0	0	0	0	0
Lanai......	0	0	0	0	0	0	0	0	0
Maui......	44	0	0	0	0	0	0	0	0
Molokai...	0	0	0	0	0	0	0	0	0
Oahu......	0	0	0	0	0	0	0	0	0
Total....	547	28	5	280	28	0	0	0	0
ZONE E_3	No Lace-necked Doves								
TOTALS									
Hawaii....	4,030	1,723	43	31,570	1,059	368	296	0	0
Kauai.....	555	306	55	10,470	15	141	150	0	0
Lanai......	141	138	98	3,470	93	0	21	24	0
Maui......	728	320	44	16,730	19	5	232	64	0
Molokai...	260	184	71	13,990	0	65	12	86	21
Oahu......	604	451	75	12,450	0	358	42	51	0
Total....	6,318	3,122	49	88,680	1,186	937	753	225	21

tribution. These were made in conjunction with inventories taken of other game birds and offered us the most suitable means for establishing satisfactory estimates of population densities. It is realized that a daytime population estimate may include some birds feeding but not roosting in a given zone. However, in the overall population estimate, any error due to this fact appears to be of little consequence. Much of the daily movement takes place within a vegetation zone, and where flyways do exist, they are generally found between vegetation zones A, B, and C_1, all of which rank as dove range of equal quality on the basis of strip-count estimates. Field observations on the amount of available dove food and the occurrence of roosting cover correspond to the general ratings of vegetation zones by population estimates.

An analysis of Table 1 shows zones A, B, and C_1 to be the best zones for Lace-necked Doves. They all have high percentages of occupancy (89–90 per cent), high populations (16,000–29,000), and include very high

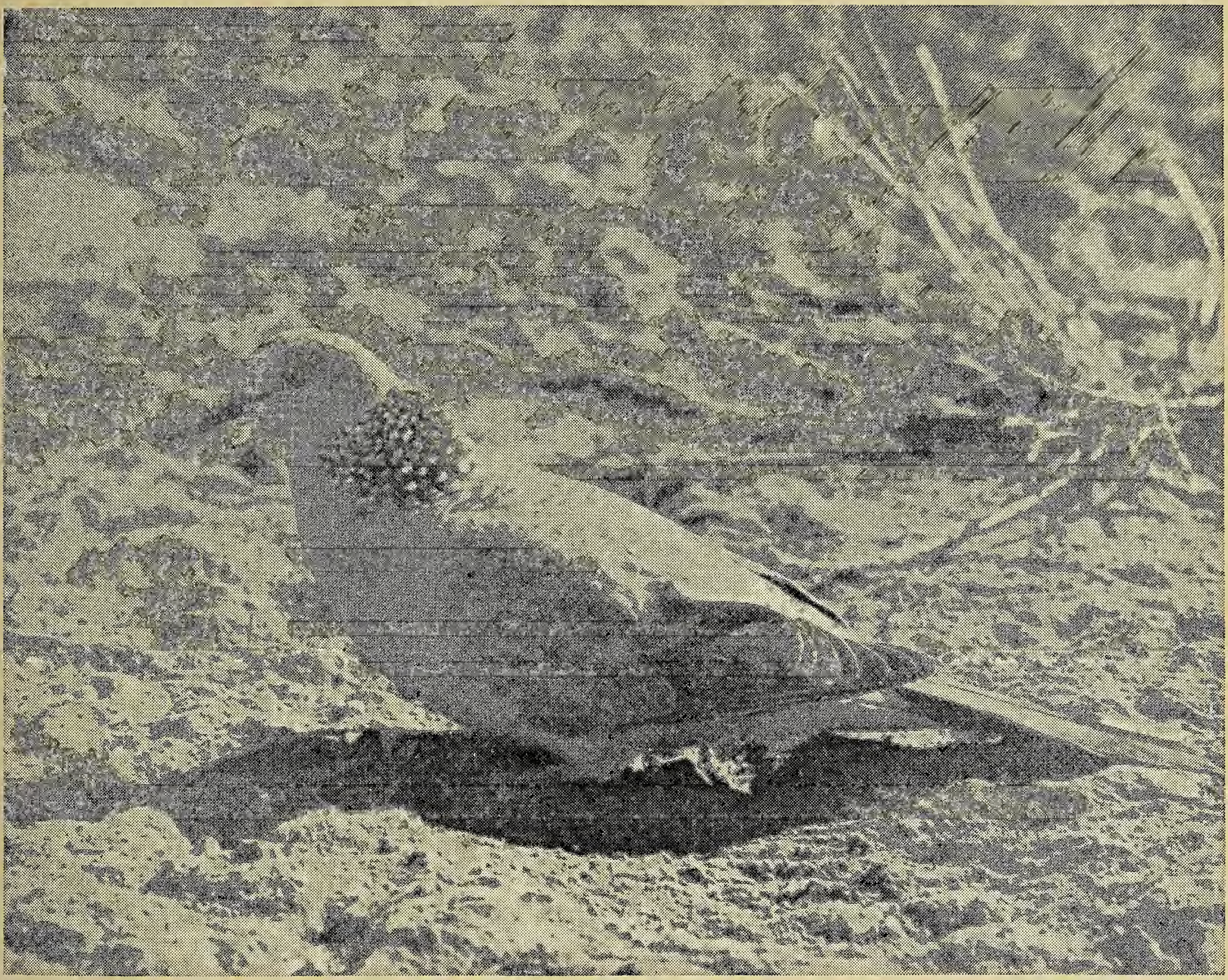
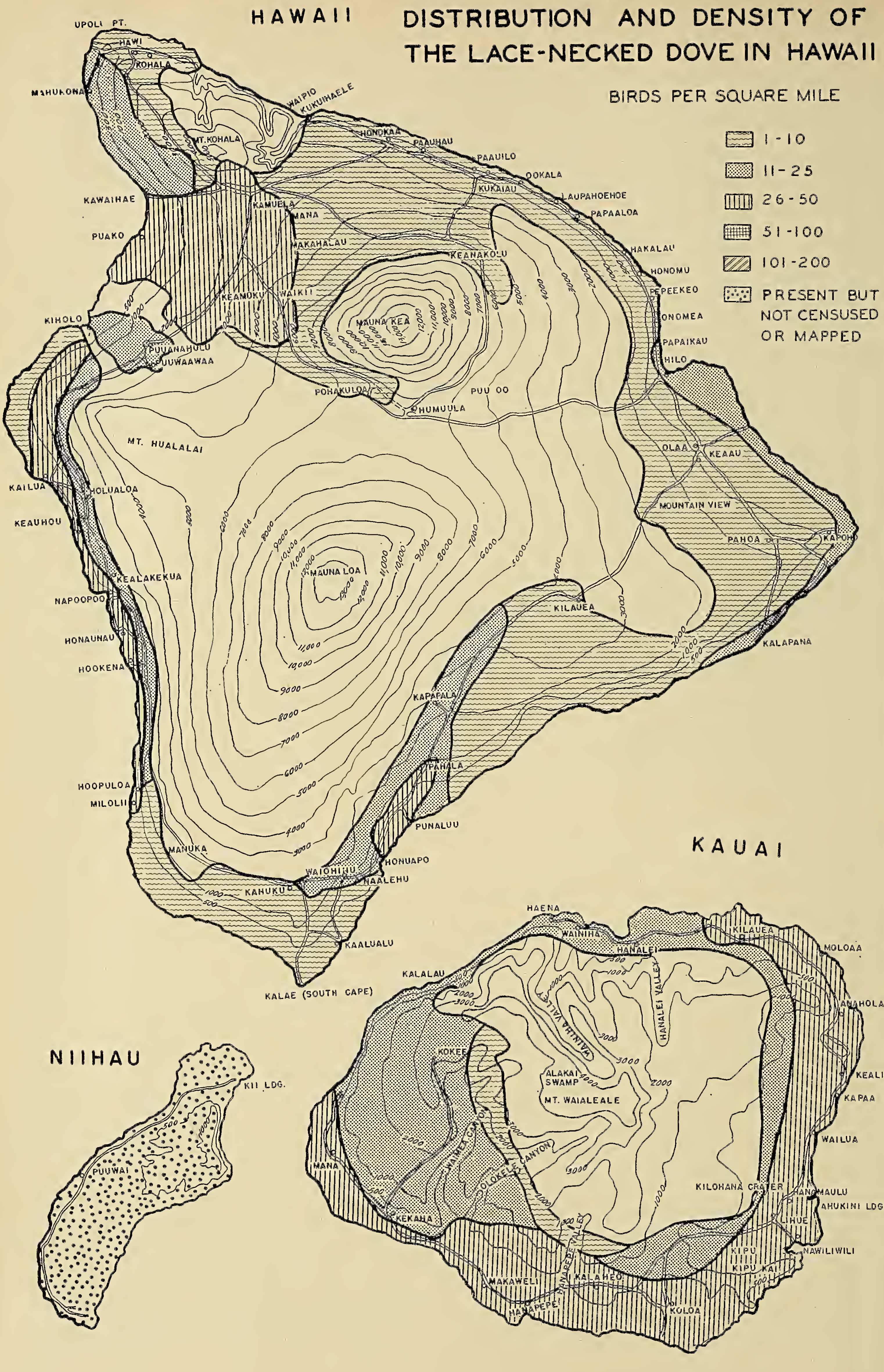


FIG. 1. Adult Lace-necked Dove. Waikii, Hawaii. Elevation 4,700 feet above sea level; April 5, 1946.

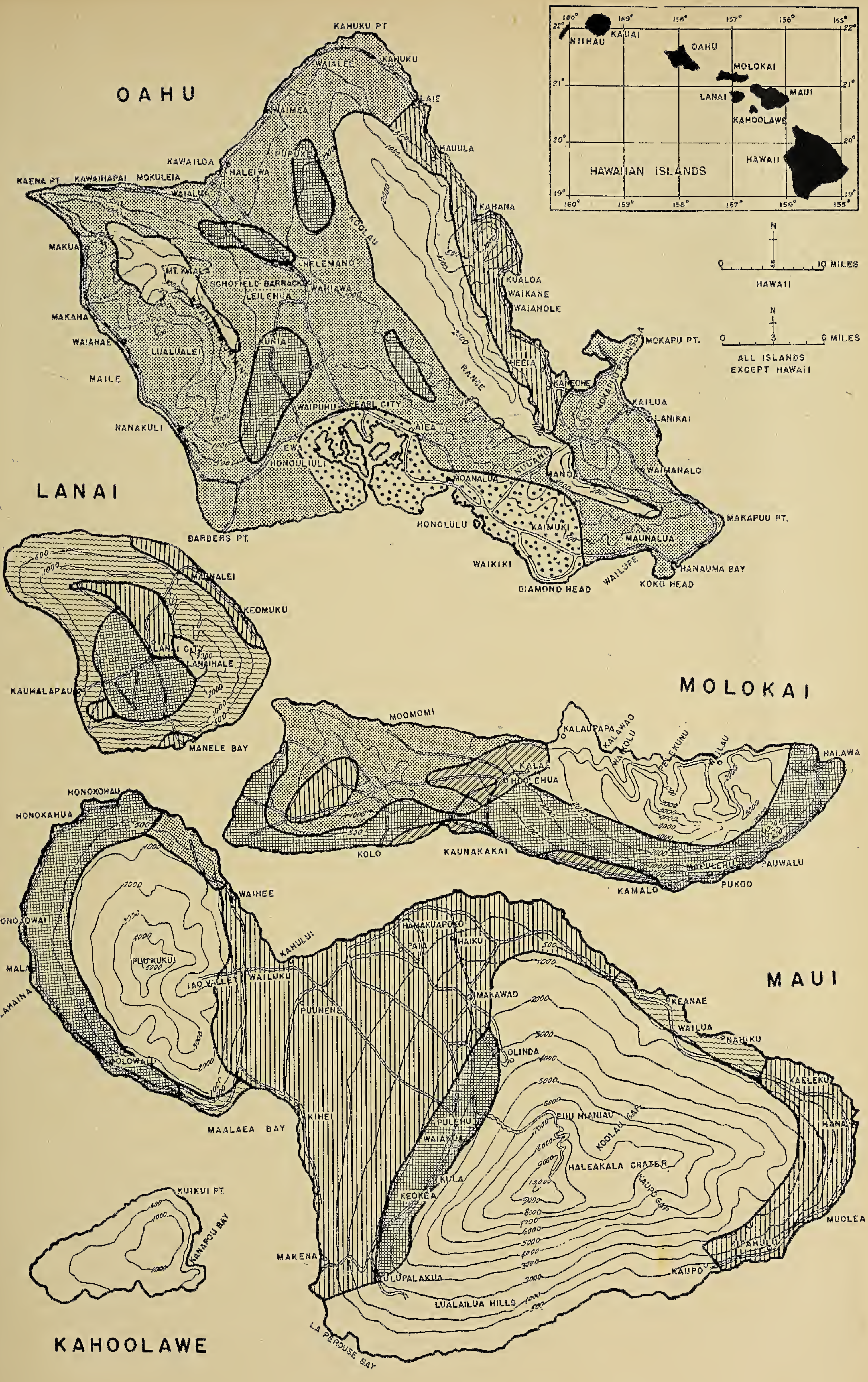
densities (up to 200 birds per square mile). These zones occupy the coastal regions below 2,500 feet elevation, where mean temperatures are between 75° and 70° F. annually and where rainfall varies from less than 10 to approximately 60 inches annually. The densest populations in these zones occur on Molokai and are the result of a desirable combination of habitat requirements. One of the most productive areas centers in the region of pineapple cultivation near Hoolehua. A resident population of doves utilizes densely wooded draws and gullies for roosting areas, and forages in old pineapple fields rich in weedy growth and in fallow grain fields and garden plots of adjacent homestead areas. Water is obtained from the fruit of popolo (*Solanum nodiflorum*), scattered livestock watering places, and occasional rain and dew. Two other regions of dove concentration on this island are found in the coastal flats and in areas immediately adjacent. Here, in the excellent roosting sites afforded by algaroba (*Prosopis chilensis*) are numerous stock watering units and some springs. On the adjacent dry open slopes, xerophilous plants such as uhaloa (*Waltheria americana*) and ilima (*Sida* sp.) produce an abundant seed crop utilized by these doves. Between these areas and the Hoolehua area there is considerable exchange of birds, which results in definite flyways.

Zones C_2 and D_1 are classed as intermediate dove range because of an intermediate percentage of occupancy (62–81 per cent), intermediate population (8,000–13,000), and intermediate densities (generally up to 100 birds per square mile). In these zones,

Fig. 2.



DISTRIBUTION AND DENSITY OF THE LACE-NECKED DOVE IN HAWAII


HAWAIIAN ISLANDS
NIIHAU
KAUAI
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HAWAII
160°
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157°
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155°
22°
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5
10 MILES
HAWAII
N
0
3
6 MILES
ALL ISLANDS EXCEPT HAWAII
OAHU
KAHUKU PT
KAHUKU
WAIALEE
LAIE
WAIMEA
PUPUKEA
HAUULA
KAWAILOA
KAENA PT.
KAWAIHAPAI
MOKULEIA
HALEIWA
WAIALUA
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MT. KAALA
HELEMANO
SCHOFIELD BARRACKS
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WAHIAWA
KOOLAU
KUALOA
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WAIANAE
LUALUALEI
KUNIA
RANGE
HEEIA
KANEOHE
MOKAPU PT.
MOKAPU PENINSULA
MAILE
WAIPUHU
PEARL CITY
AIEA
KAILUA
LANIKAI
NANAKULI
EWA
HONOULIULI
MOANALUA
NUUANU
MANOA
WAIMANALO
HONOLULU
KAIMUKI
MAKAPUU PT.
MAUNALUA
BARBERS PT.
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DIAMOND HEAD
WAILUPE
KOKO HEAD
HANAUMA BAY
LANAI
MAUNALEI
KEOMUKU
LANAI CITY
LANAIHALE
KAUMALAPAU
MANELE BAY
MOLOKAI
MOOMOMI
KALAUPAPA
KALAWAO
WAIKOLU
PELEKUNU
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HONOKOWAI
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IAO VALLEY
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KIHEI
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KOOLAU GAP
KAELEKU
HANA
HALEAKALA CRATER
KAUPO GAP
KULA
KEOKEA
MUOLEA
KIPAHULU
MAKENA
ULUPALAKUA
KAUPO
LUALAILUA HILLS
LA PEROUSE BAY
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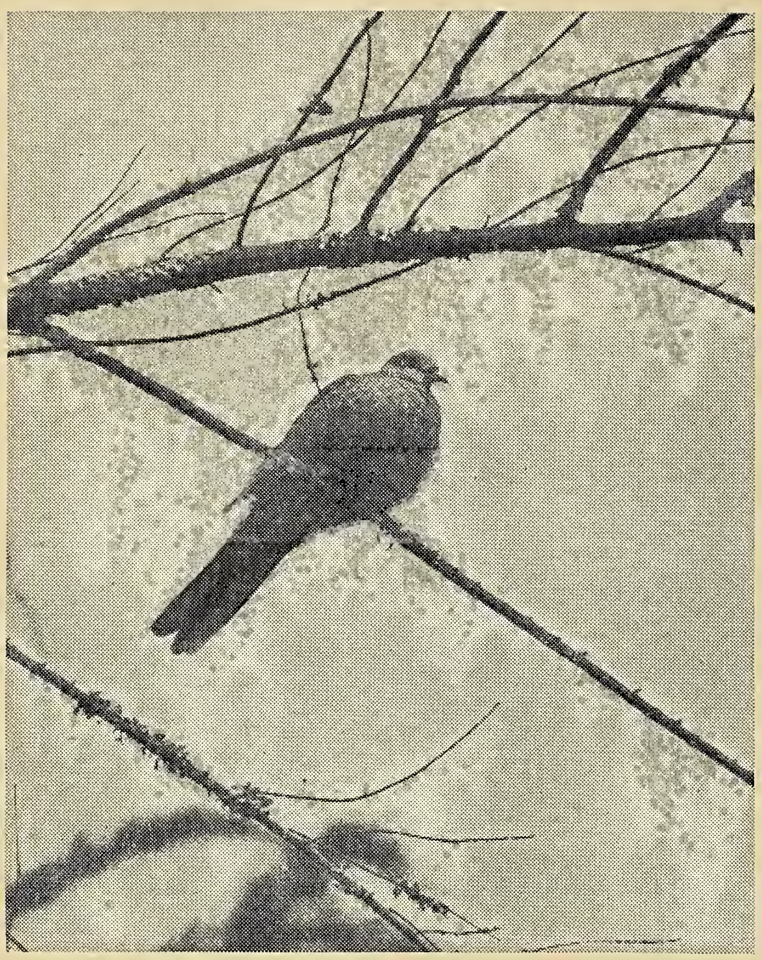

FIG. 3. Adult Lace-necked Dove. Waikii, Hawaii. Elevation 4,700 feet above sea level; April 5, 1946.

abundant food, available either seasonally or locally, is primarily responsible for the best densities, but the possible factors believed to limit high dove populations are different for the two zones. Zone C_2 lies between 2,500 and 4,000 feet elevation, where the annual mean temperature is 60° F. and the average rainfall is between 40 and 60 inches annually. This temperature is lower than those in the best Lace-necked Dove zones and is suggested as possibly being able to inhibit high populations. Zone D_1, occurring between sea level and approximately 1,500 feet elevation, has an annual mean temperature of about 73° F. and an annual rainfall with a minimum of 60 inches. It is probable that the numerous and often heavy rains affect nesting success in this zone.

The poorest dove ranges occur in zones D_2, D_3, E_1, and E_2, which show low percentages of occupancy (5–21 per cent), poor populations (280–1,800), and generally low densities (50 or fewer birds per square mile). Zone D_2 lies between the general elevations of 1,500 and 4,000 feet, where the annual mean temperature is 60° F. and rainfall reaches 450 or more inches annually. Low temperatures, heavy rainfall, and the lush forest cover all prohibit high densities. Doves are found only where suitable foods occur in small openings cleared for cultivation or resulting from heavy grazing. The other three zones, D_3, E_1, and E_2, are above 4,000 feet elevation, where mean temperatures vary between 50° and 40° F. annually, and the extremes of rainfall are from about 100 inches at lower elevations to less than 40 inches at higher elevations. The cold temperatures probably contribute largely to the prevailing poor densities, but at lower elevations (D_3) the heavy rainfall is another adverse factor. Dove foods are extremely limited in these zones and water is unavailable in E_1 and E_2.

Nearly all informed persons interviewed during this survey expressed the opinion that Lace-necked Doves have been decreasing in recent years. Many believe that competition for food between this species and the more plentiful and more recently introduced Barred Dove, *Geopelia striata striata* (L.), is the cause of this decrease but data from our food studies given below indicate otherwise. It may be significant that on Hawaii, where the Barred Dove is just becoming established in only a few localized areas, the same islandwide decrease of the Lace-necked Dove is also reported.

FOODS

An analysis was made of Lace-necked Dove foods from 146 crops and 71 gizzards. Each food species in the crop was identified, separated, measured in cubic centimeters, totaled by aggregate volume, and recorded for occurrence. Gizzard contents were identified and recorded for occurrence only. Every month except January and all islands except Niihau and Kahoolawe were represented in the sample. Except for four doves, all were collected between sea level and 2,700 feet elevation in zones A, B, C_1, C_2, and D_1, and

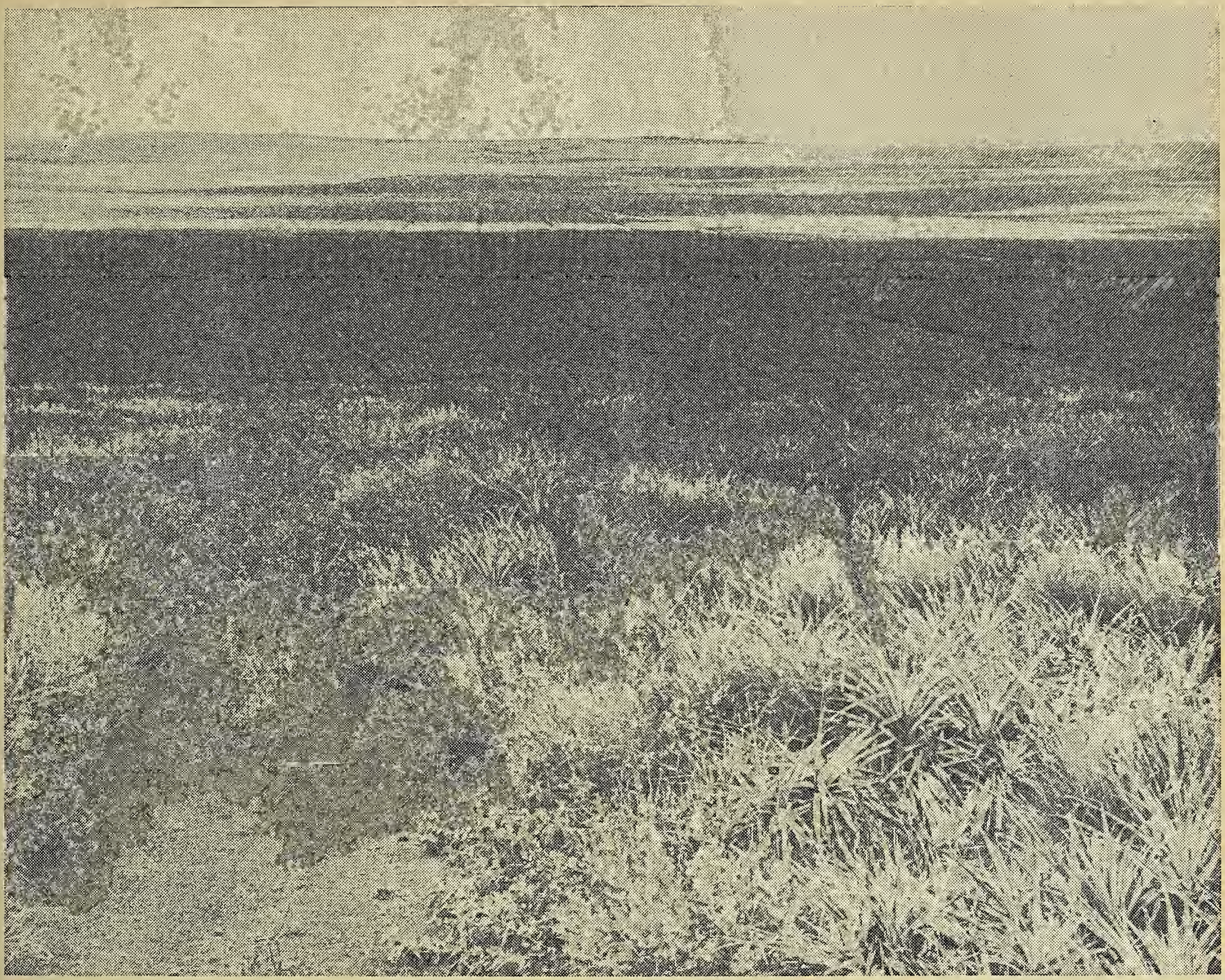

FIG. 4. Lace-necked Doves frequently feed in the fallow sections (foreground) of pineapple fields which support a rich growth of herbaceous annuals. The cultivated pineapple fields (background) are seldom utilized by this species. Lanai. Vegetation zone B, elevation 1,500 feet above sea level; August 27, 1946.

from the distribution of the food species in the Islands, it was obvious that feeding occurred almost entirely within this area. No great seasonal difference occurs in the food supply of doves in Hawaii although there may be periods when individual plant species produce seeds more abundantly, especially following rains in the drier regions. This food analysis was not made according to vegetation zone, as was done for most other game birds during this survey, for two reasons: Some doves collected on flyways were suspected of having fed in a vegetation zone different from the one in which they were taken; also, only a few zones which comprise dove range in the lower elevations are used in this food analysis.

Table 2 lists the foods of the Lace-necked Dove in Hawaii. Sixty-five plant species form 99.5 per cent of the diet and 13 animal items constitute the remaining 0.5 per cent. Of the plant foods, seeds and pods form 84.1 per cent, succulent fruits constitute 14.4 per cent, and roots and seedlings comprise the remaining 1.0 per cent. The nine most important foods on the basis of volume and and frequency of occurrence in crops (more than 2 per cent or more than 14 occurrences) are discussed briefly.

Momordica Balsamina L., balsam apple, is an exotic member of the family Cucurbitaceae and forms 23 per cent of the foods taken. It occurred in 43 (29 per cent) of the crops and 16 (22 per cent) of the gizzards. Although its

TABLE 2

FOODS OF THE LACE-NECKED DOVE IN HAWAII

SPECIES AND PARTS EATEN	PERCENTAGE CROP VOLUME	NUMBER OCCURRENCES IN 146 CROPS	NUMBER OCCURRENCES IN 71 GIZZARDS	ABUNDANCE OF FOOD BY VEGETATION ZONE*								
				A	B	C1	C2	D1	D2	D3	E1	E2
PLANTS	99.5											
Momordica Balsamina, balsam apple; seed	23.1	43	16		o	o						
Waltheria americana, uhaloa; seed	17.6	57	27	o	c	c	o					
Cajanus Cajan, pigeon pea; seed	12.8	21	4		r	o	r	r				
Solanum nodiflorum, popolo; fruit, seed	10.0	19	11		o	c		o				
Lantana Camara, lantana; fruit, seed	9.6	7	7	o	a	c		o				
Wikstroemia phillyraefolia, akia; fruit, seed	4.4	5	3		r	o						
Portulaca sclerocarpa, ihimakole; seed, pod	3.7	17	0		r							
Dianella sandwicensis, ukiuki; fruit, seed	3.1	1	1					o	o			
Sida sp. (*cordifolia*), ilima; seed and	2.9	32	10	o	c	r						
Sida sp. (*fallax*), ilima; seed†				c	a	c						
Hordeum vulgare, barley; seed	1.9	1	1				r					
Centaurea melitensis, Maltese thistle; seed	1.3	7	3	o	o							
Unidentified seeds	1.1	16	6									
Euphorbia hypericifolia, graceful spurge; seed	0.9	5	4		o	o						
Grevillea robusta, silk oak; seed	0.9	3	3		o	c						
Ananas comosus, pineapple; root	0.9	3	1	cul	tivat	ed						
Zea mays, corn; seed	0.8	4	1	cul	tivat	ed						
Aleurites moluccana, kukui; seed	0.7	1	1			o		c	c			
Verbena litoralis, verbena; seed	0.7	2	2		o	c	c				c	
Phytolacca octandra, pokeberry; fruit	0.4	4	5		r	r						
Atriplex semibaccata, Australian salt bush; seed	0.4	4	2	c	r							
Euphorbia geniculata, wild euphorbia; seed	0.3	1	1			o	o					
Opuntia megacantha, panini or cactus; seed	0.3	2	4	o	c	o						
Prosopis chilensis, algaroba or kiawe; seed pod, seedling	0.3	3	2	a	c							
Sida rhombifolia, ilima; seed	0.3	8	5		o	r						
Euphorbia hirta, garden spurge; seed	0.2	4	1		o	c						
Avena fatua, wild oat; seed	0.1	1	0		r	r	c					
Carica papaya, papaya; seed	0.1	1	0	cul	tivat	ed						
Eugenia Cumini, Java plum; fruit	0.1	2	1		o	o		o				
Portulaca cyanosperma, small pigweed; seed	0.1	1	1	c								
Ricinus communis, castor bean; seed	0.1	1	1		o	o	r					
Siegesbeckia orientalis, small yellow crown beard; seed	0.1	6	5			o		r				
Tephrosia purpurea, ahuhu; seed	0.1	13	5	o	r							

*From Ripperton and Hosaka (1942). a = abundant; c = common; o = occasional; r = rare.

†The seeds of these species are practically indistinguishable, hence they are combined herein.

TABLE 2 (Continued)
FOODS OF THE LACE-NECKED DOVE IN HAWAII

SPECIES AND PARTS EATEN	PERCENTAGE CROP VOLUME	NUMBER OCCURRENCES IN 146 CROPS	NUMBER OCCURRENCES IN 71 GIZZARDS	ABUNDANCE OF FOOD BY VEGETATION ZONE*								
				A	B	C1	C2	D1	D2	D3	E1	E2
PLANTS continued												
Xanthium saccharatum, cocklebur; seed	0.1	1	0	o	c	o						
Unidentified seedling	0.1	1	0									
Abutilon molle, mao; seed	T	5	3	r	o							
Amaranthus hybridus, spleen amaranth; seed	T	6	2		o	o						
Argemone alba var. *glauca*, puakala; seed	T	4	0	o	c							
Bidens pilosa, pilipili; seed	T	1	1	o	c	c	o	o	r			
Brassica sp., mustard; seed	T	2	0									
Cassia occidentalis; seed	T	1	0		o	o		r				
Casuarina sp., ironwood; seed	T	2	1									
Chenopodium ambrosioides, Mexican tea; seed	T	1	1		r						r	
Cirsium vulgare, common thistle; seed	T	3	3			o	c				o	
Cuphea carthagenensis, tarweed; seed pod	T	1	0			o		c	o			
Dodonaea viscosa, aalii; seed	T	6	14		o	o	o				o	
Echinochloa crusgalli var. *cruspavonis*, barnyard grass; seed	T	1	0		c	c						
Eleusine indica, wire grass; seed	T	1	0		r	o		r				
Fungus, puff ball	T	1	0									
Geranium carolinianum var. *australe*, wild geranium; seed	T	1	1				c		o	o	r	
Ipomoea sp.; seed	T	1	0									
Leucaena glauca, koa haole; seed	T	1	0	c	a	c		o				
Malva parviflora, little mallow; seed	T	1	2		o	c	o					
Malvastrum coromandelianum, false mallow; pod, seed	T	1	1	o	c							
Mimosa pudica, sensitive plant; seed	T	1	1			o		c	r			
Portulaca oleracea, pigweed; seed, pod	T	1	0	r	o	c		o				
Setaria verticillata, bristly foxtail; seed	T	3	3	c	o	o						
Sporobolus capensis, rattail; seed	T	1	2		r	o	c			o	o	
Triticum aestivum, wheat; seed	T	1	0	i	mpo	rted	cat	tle	feed			
Cassia Leschenaultiana, Japanese tea; seed	0	0	4		c	c		r				
Chenopodium oahuense, aweoweo; seed	0	0	1		o	o					o	
Desmodium uncinatum, Spanish clover; seed	0	0	2		r	c	c	c	r		r	
Indigofera suffruticosa, indigo; seed	0	0	1		r	c	o	r				
Paspalum Urvillei, vasey grass; seed	0	0	1			r	r	r				
Plantago sp.; seed	0	0	1									
Psidium Guajava, guava; seed	0	0	5		o	c		a	o			
Styphelia Tameiameiae, puakeawe; seed	0	0	3			o	o				o	o

TABLE 2 (Continued)

Foods of the Lace-necked Dove in Hawaii

SPECIES AND PARTS EATEN	PER-CENTAGE CROP VOLUME	NUMBER OCCUR-RENCES IN 146 CROPS	NUMBER OCCUR-RENCES IN 71 GIZ-ZARDS	ABUNDANCE OF FOOD BY VEGETATION ZONE*								
				A	B	C_1	C_2	D_1	D_2	D_3	E_1	E_2
ANIMALS	0.5											
Megacerus alternatus, pea weevil; adult	0.2	10	0									
Carpophilus humeralis, yellow-shouldered souring beetle; adult	0.2	3	2									
Carpophilus hemipterus, dried fruit beetle; adult	0.1	3	2									
Antonina graminis, scale insect; fragment	T	2	0									
Blattidae (unidentified), cockroach; egg case	T	7	0									
Cirphis unipuncta, army worm; larva	T	1	0									
Coccidae (unidentified), scale insects; adult	T	1	0									
Coleoptera (unidentified), beetles; adult	T	1	0									
Conoderus exsul, wireworm; larva, pupa	T	4	0									
Crustacea (unidentified), crayfish; chitin	T	1	0									
Lepidoptera (unidentified), butterflies, moths, skippers; larva	T	1	0									
Mollusca (unidentified), aquatic snail; shell	T	1	0									
Rodentia (unidentified), rodent; tooth	T	1	0									

general distribution is only occasional in zones B and C_1, it grows very profusely during all seasons in certain areas, particularly in fallow pineapple fields and along roadsides. Lace-necked Doves show a preference for the large seeds, and concentrations of feeding birds occur where this plant is abundant and in seed.

Waltheria americana L., or uhaloa, comprising 17 per cent of the entire diet, ranks as an important food. Its seeds occurred in 57 (39 per cent) of the crops and 27 (38 per cent) of the gizzards. Uhaloa grows occasionally in zones A and C_2 but commonly in B and C_1. This exotic member of the Sterculiaceae appears to produce seeds abundantly throughout the year. Widely available in arid sections at low elevations, this plant apparently plays a prominent role as a food in these regions where seed productivity is otherwise low. We also found uhaloa to be an important food of the Barred Dove and the California Quail (*Lophortyx californica*) in Hawaii.

Cajanus Cajan (L.) Millsp., pigeon pea, constitutes 12 per cent of the Lace-necked Doves' food. Twenty-one (14 per cent) of the crops and 4 (5 per cent) of the gizzards contained these seeds. This exotic legume is rare in zones B, C_2, and D_1, but occasional in zone C_1, where it occurs chiefly as cultivated cattle forage. Seeds are available throughout the year.

Solanum nodiflorum Jacq., or popolo, grows occasionally in zones B and D_1 but commonly in zone C_1, particularly in old pineapple fields. The fruit and seeds of this indigenous species of the Solanaceae comprised 10 per cent of the diet and occurred in 19 (13 per cent) of the crops and 11 (15 per cent) of the gizzards. Field observations show that doves often gorge themselves on these succulent fruits, which are available all year. It is possible that moisture provided by this fruit may entirely eliminate the need for surface drinking water. Popolo is also an important food of pheasants (*Phasianus torquatus* Gmelin and *P. versicolor* Veillot) in Hawaii.

Lantana Camara L. is an exotic verbena which accounted for 9 per cent of the diet. The fruits and seeds were taken in only 7 (4 per cent) of the crops and 7 (9 per cent) of the gizzards. *Lantana* is abundant in zone B, common in C_1, and occasional in A and D_1, and this distribution makes it widely available throughout dove range. However, its relatively infrequent occurrence and small volume in the diet implies that it is not a generally preferred food. Almost the entire volume of this plant in the food analysis came from four Lace-necked Doves taken at Koloa, Kauai, in zone C_1. Two Barred Doves collected at the same place and time had also eaten large quantities of *Lantana* although it was not a common food of Barred Doves. Possibly the *Lantana* here was particularly attractive at this time or other foods may have been lack-

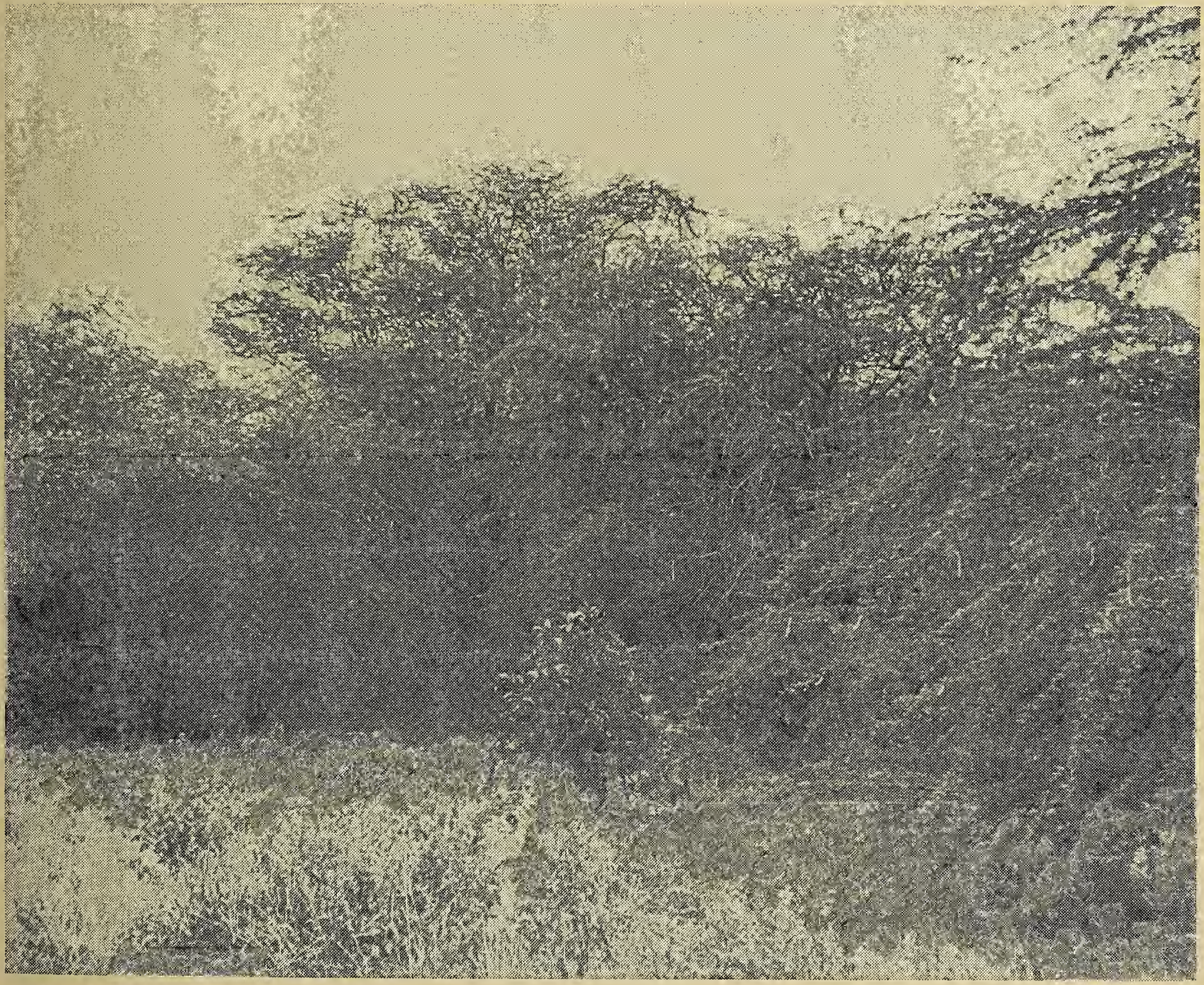

FIG. 5. The dense coastal stands of algaroba (*Prosopis chilensis*) furnish good roosting and nesting sites for the Lace-necked Dove. Openings as shown in the foreground support food species such as uhaloa (*Waltheria americana*), ilima (*Sida* sp.), and *Lantana Camara*. Kekaha, Kauai. Vegetation zone A, sea level; October 6, 1946.

ing. Perkins and Swezey (1934) have accredited the Lace-necked Dove with being a principal agent in the wide dissemination of *Lantana* throughout coastal areas. However, the limited feeding on *Lantana* and the fact that all *Lantana* seeds in gizzards were ground up indicates to us that Lace-necked Doves may have contributed little to the spread of this noxious shrub. Probably of greater importance in permitting its spread in the Islands was the lack of natural checks on this exotic plant in its new environment.

The seeds and fruits of *Wikstroemia phillyraefolia* Gray, locally known as akia, were utilized by Lace-necked Doves as 4 per cent of the diet. They occurred in 5 (3 per cent) of the crops and 3 (4 per cent) of the gizzards. The small volume and rare occurrence in the diet are probably related to the distribution of akia, which is rare in zone B and occasional in C_1. However, on certain lava outcrops in zone C_2 on Hawaii, this endemic species of the Thymelaeaceae is abundant and is believed to be a preferred food because of its intensive utilization by Lace-necked Doves there. The fruits of this plant, too, furnish a ready supply of moisture. Akia, obtainable during all seasons but most abundantly during spring, summer, and fall, also ranks as an important food of pheasants and feral pigeons (*Columba livia* Gmelin) in Hawaii.

Portulaca sclerocarpa Gray, or ihimakole, formed 3 per cent of the food of Lace-necked Doves. It occurred in 17 (11 per cent) of the crops but in no gizzards. Both seed pods and seeds of this endemic species of the Portulacaceae are fed upon in zone B, where it occurs rarely.

Dianella sandwicensis Hook. and Arn., or ukiuki, grows occasionally in zones D_1 and D_2. The crop and gizzard of only one bird contained seeds and fruits of this plant, which amounted to 3 per cent of the total foods. This bird was taken from zone D_3 at Kokee, Kauai, where the ukiuki fruits abundantly during summer and fall. Doves in this section have been observed to feed upon the seeds and fruits of this species but because of its limited distribution and the scarcity of Lace-necked Doves in this zone, it cannot be considered a major food. This endemic lily is an important food of pheasants and Jungle Fowls (*Gallus gallus* (L.)) in this area.

Sida cordifolia L. and *Sida fallax* Walpers, both called ilima, are indigenous species of the family Malvaceae. Because their seeds are practically indistinguishable, their utilization has been combined as 2 per cent of the Lace-necked Doves' food. These plants occurred in 32 (21 per cent) of the crops and 10 (14 per cent) of the gizzards. The former species is occasional in zone A, common in B, and rare in C_1, while the latter is common in zones A and C_1 and abundant in B. These species produce seeds abundantly throughout the year although during some drouth periods production is slackened. They, combined with uhaloa, provide a desirable combination of foods in drier and more barren parts of dove range.

The remaining plant and animal foods appear to be of less importance because of their small volumes and the infrequencies of their occurrence in the diet. However, as contributions to variety and to nutrition they are doubtless of value. Most plants in this group are widely available in areas from which birds were collected. In many parts of the range there is apparently sufficient food to support higher dove populations than now exist.

Grit occurred in 17 crops and 38 gizzards and averaged 0.3 cubic centimeter in both cases; 10 additional gizzards had traces of grit while 23 had none. Both angular and well-rounded pieces of feldspar, olivine, basalt, quartz, bottle glass, opaline, and round concretions of hard earth, from 1 to 4 millimeters in diameter, were found.

FEEDING, WATERING, AND ROOSTING HABITS

Feeding is occasional from an hour or more after daylight until about noon, when it is greatly accelerated. In those areas of abundant food far removed from roosting sites, Lace-necked Doves infiltrate irregularly throughout the morning, reaching an apparent maximum number about noon. Heaviest feeding takes place during the next few hours. Beginning about 3:00 P.M. birds with full crops (averaging 10.1 cubic centimeters in 85 birds with a maximum of 35.1 cubic centimeters) start returning singly or in groups of twos or threes along definite flyways to their roosting sites. Distances of at least 5 miles are often traveled between feeding grounds and communal, coastal roosting sites but doves may reside in certain roosting areas with available food.

Lace-necked Doves and Barred Doves often feed in the same fields, giving rise to the local opinion that serious competition for foods occurs between these species. However, Lace-necked Doves select principally large seeds and fruits while Barred Doves utilize small-seeded, rapidly maturing annuals and grasses (Schwartz and Schwartz, 1949). As a result of these food preferences, the use of these fields by each species is generally at different stages of cultivation or plant succession. Although some of the foods eaten by both doves may be of the same species, it is highly significant that only one plant, uhaloa, is an important food in the diet of both birds. This shrub occurs in great abundance throughout most dove range and the seeds are more than ample to supply the needs of both species of doves as well as of other game birds which also utilize them.

Our observations indicate that either fresh or brackish surface water or succulent fruit is a prerequisite for good Lace-necked Dove range. Birds resident in areas without available surface water appear to substitute succulent fruits in fulfilling their daily water needs. Elsewhere, doves readily utilize cattle troughs (especially overflow or seeps), irrigation ditches, reservoirs, pools, streams, and springs, in addition to rainfall and dew which may collect in the leaf axils of many plants. The proximity of these water sources to feeding and roosting areas plays an important role in the daily range. Customarily, Lace-necked Doves use water close to their feeding area in late afternoon but in the morning resort to a water source near their roosts. At these latter sites they may linger and bathe and preen their feathers before venturing out to their foraging grounds for the day. In some dry sections, existing water holes now attract doves over approximately a 5-mile radius. The presence of water within flying range of the nest has been shown by Arnold (1943) to be a necessity for the western White-winged Dove, *Zenaida asiatica mearnsi* (Ridgway), and it is not unlikely that a similar requirement holds for the Lace-necked Dove in Hawaii.

Roosting areas are usually dense wooded thickets of algaroba on the coastal flats, dense groves of *Eucalyptus* sp. or of ironwood (*Casuarina* sp.), or the peripheries of forested areas and wooded draws radiating therefrom, although some roosting occurs in practically any timbered area. In some parts of the Islands, Lace-necked Doves tend to be gregarious in their roosting habits, and the commonest community roosting sites in the dense coastal stands of algaroba harbor nightly populations of a hundred or more birds per acre.

BREEDING

From the little evidence accumulated during this survey, we believe that Lace-necked Doves breed mostly from February through September and possibly, to a limited extent, during the entire year.

We noticed that the "cooing" song of the males becomes greatly accelerated during January and for the next 2 months is increasingly obvious during the early morning hours and to a lesser extent during the day. After a peak from mid-March through mid-July, the intensity of "cooing" in the general population gradually diminishes until by late October occasional courting songs are heard

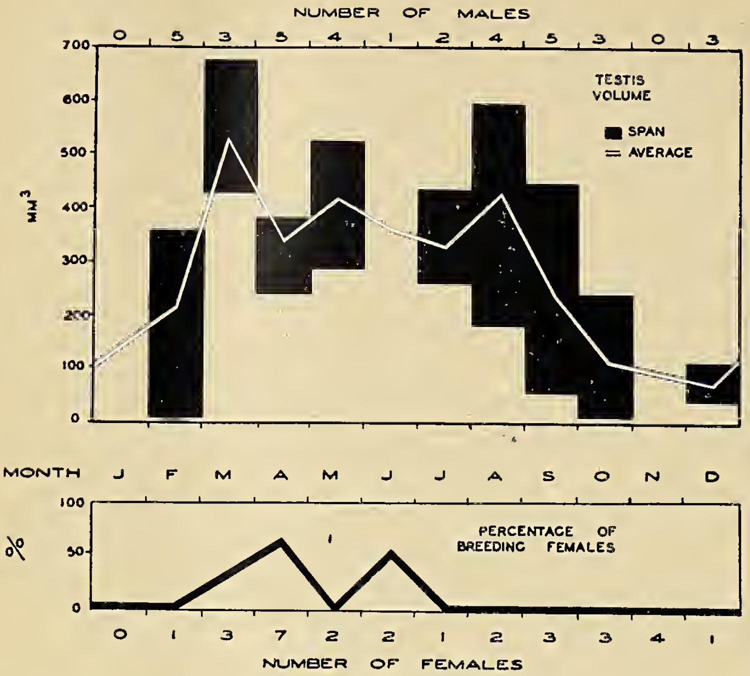

FIG. 6. Breeding of the Lace-necked Dove in Hawaii.

only in early morning. These variations in vocal activity generally coincide with fluctuations in testis volumes (roughly computed by multiplying length × width × depth of both testes per individual) of 35 collected adult males, and with indications of breeding (determined by the presence of maturing Graafian follicles) in 29 collected adult females (Figure 6). We do not believe that breeding is common after September, as evidenced by the fact that 86 birds collected from October through December all were in adult plumage.

In southern China, the breeding season of the species *S. chinensis* is spring, summer, and autumn (La Touche, 1931–34) and in India these doves are reported to breed throughout the year (Ali, 1944) and probably to raise several broods annually (Whistler, 1935). Breeding of this species in the Malay Peninsula generally extends from January to March, but extremes from November to May occur (Robinson and Chasen, 1936).

In Hawaii, the Lace-necked Dove shows a wide selection of nesting sites. Typical ones observed during this survey are as follows: (1) in a strong crotch 10 feet above the ground in an algaroba tree; (2) 35 feet above the ground in the outer branches of an algaroba tree; (3) in a clump of cactus (*Opuntia megacantha*) on a sloping stem 6 feet above the ground; (4) in a thicket of *Smilax* sp. and akala (*Rubus hawaiensis*) growing on the rim of a gulch 25 feet deep; (5) 18 feet above the ground in the outer fringes of a mamani tree (*Sophora chrysophylla*); (6) 5 feet above the ground in a puakeawe bush (*Styphelia Tameiameiae*); (7) 35 feet above the ground in the outer branches of an ironwood tree.

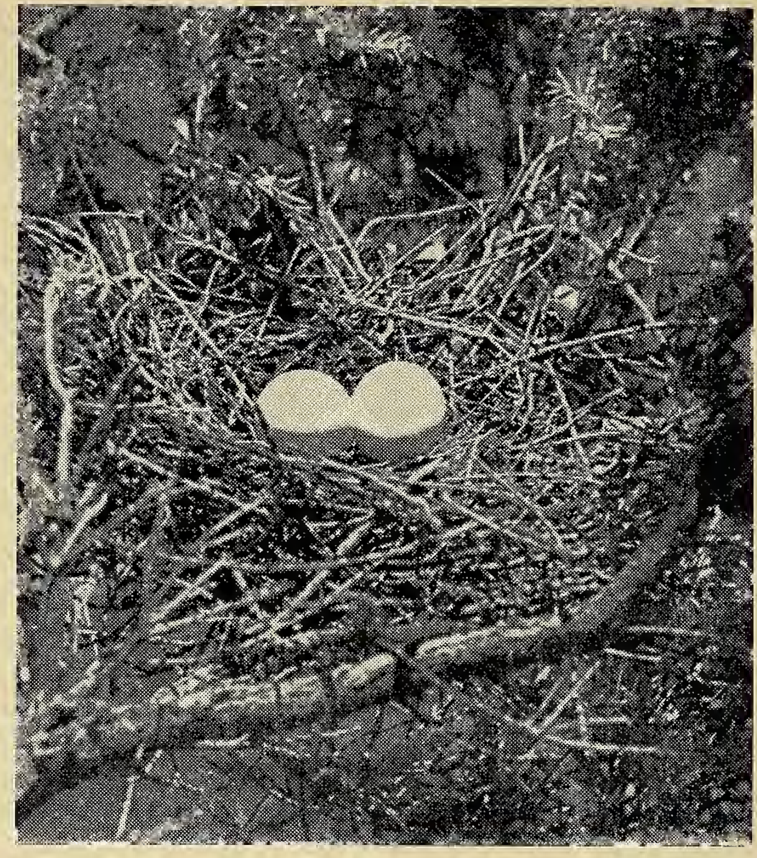

FIG. 7. A Lace-necked Dove nest in puakeawe (*Styphelia Tameiameiae*). Kapapala, Hawaii. Vegetation zone C_2, elevation 4,000 feet; June 8, 1946.

The nest is typically dove-like, consisting

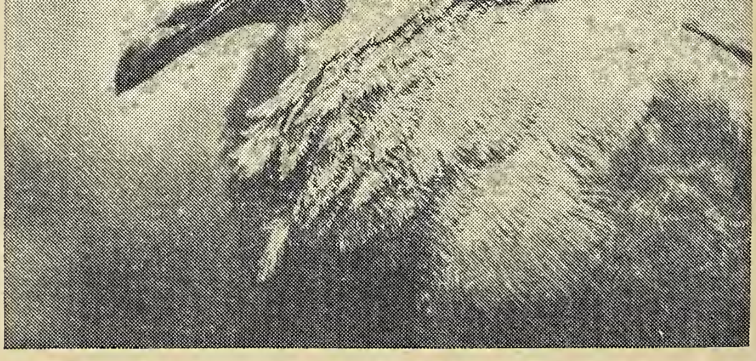

FIG. 8. Juvenile Lace-necked Dove. Note the lack of the neck "lace" so characteristic of the adult. Honolulu, Oahu. Sea level; May 15, 1946.

of a flimsy platform about 7 inches in diameter, roughly constructed of twigs between ⅛ and ¼ inch in diameter and about 4 or 5 inches long. Sometimes it contains a lining of fine rootlets for the two white eggs.

The juvenile plumage lacks the black and white neck "lace" so characteristic of the adult, and the contour feathers are distinctly and narrowly light-tipped. Three nest-free birds in juvenile plumage had bursae of Fabricius 4 to 5 millimeters in length. Thirteen birds in adult plumage had no measurable bursae while two others had bursae measuring 3 and 5 millimeters, respectively. Riddle (1928), working with other species of *Streptopelia*, found that bursae usually, but not invariably, involuted at sexual maturity.

SEX RATIOS, WEIGHTS, AND MEASUREMENTS

Sex ratios found in the Lace-necked Dove in Hawaii are as follows:

	NUMBER OF MALES	NUMBER OF FEMALES	MALES PER 100 FEMALES
79 adult and nest-free juvenile doves	43	36	119:100
64 adults	35	29	120:100
15 juveniles	8	7	114:100

Three adult males averaged 146 grams and three adult females averaged 159 grams in weight. This small series indicates that females may be heavier than males. However, measurements of 59 adult Lace-necked Doves show males to be slightly larger than females (Table 3).

PARASITES

Lice were the only external parasites observed on Lace-necked Doves and infestations were light to moderate. *Goniodes* sp. larvae, *Goniodes chinensis* Kell. & Chap., and a new species of *Columbicola*, not yet described, occurred on collected birds. The latter two species were also identified from Barred Doves in Hawaii.

Intestinal roundworms, *Ascaridia columbae* (Gmelin), were found occasionally, thus establishing a new host record for this parasite. *A. columbae* also occurred in feral pigeons in Hawaii. We found the eyeworm, *Oxyspirura mansoni* Cobbold, in Lace-necked Doves, as did Alicata (1947), and in the Japanese Quail (*Coturnix coturnix japonica* Temminck and Schlegel), and in pheasants in Hawaii. The heaviest infestation was two worms in each eye of a single dove. *Subulura brumpti* (Lopez Neyra), a cecal roundworm, occurred in a single specimen. This parasite is common in Japanese Quail and pheasants in Hawaii. Known intermediate hosts of the latter two parasites were not found in this food habits study, but doubtless are consumed by the Lace-necked Dove.

The cestode *Davainea crassula* (Rudolphi) was found in the Lace-necked Dove; this is another new host record. It also occurred in feral pigeons in Hawaii. Infestations varied from light to extremely heavy. The intermediate host of this parasite is unknown but since the diet of Lace-necked Doves includes some insects and mollusks, it is possible that

TABLE 3

AVERAGE MEASUREMENTS IN MILLIMETERS OF 59 ADULT LACE-NECKED DOVES

MEASUREMENTS	33 ADULT MALES	26 ADULT FEMALES
Total length	324.0	318.4
Extent of wing	459.4	451.0
Length of closed wing	152.4	150.0
Length of tail	145.6	141.5
Exposed culmen	17.4	16.8
Length of middle toe including nail	25.4	25.3

infestations with this cestode may occur as a result of consumption of these food forms.

ACKNOWLEDGMENTS

These observations were made during a survey of the game birds in the Hawaiian Islands as the initial step in the Federal Aid-Wildlife Program (1-R) of the Board of Commissioners of Agriculture and Forestry, Territory of Hawaii. Field work was carried out from February, 1946, through July, 1947.

We are indebted in many ways to fellow workers with the Board of Commissioners of Agriculture and Forestry, particularly Mr. C. G. Lennox, President of the Board, and Mr. V. E. Brock, Director, Division of Fish and Game; and to the owners and operators of many of the ranches and sugar cane and pineapple plantations in Hawaii.

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SUMMARY

1. Lace-necked Doves (*Streptopelia chinensis chinensis*) are permanent residents on all of the major Hawaiian Islands. A total of 3,120 square miles is occupied by an estimated 88,680 Lace-necked Doves with densities varying from less than 10 to 200 birds per square mile. The range occurs mostly from sea level to 4,000 feet elevation but in one area on Hawaii it reaches 8,000 feet. All types of land except dense forests and barren lava support doves. The optimum range occurs from sea level to 2,500 feet elevation. Here, the mean annual temperature is between 75° and 70° F. and extremes in the annual rainfall are from less than 10 to approximately 60 inches. Where rainfall is greater and/or temperatures lower, lesser populations occur.
2. An analysis of foods in 146 crops shows that 65 plant species comprise 99.5 per cent of the diet while 13 animal items constitute the remaining 0.5 per cent. Of the plant matter, seeds and pods amount to 84.1 per cent, succulent fruits 14.4 per cent, and roots and seedlings 1.0 per cent. Grit occurred in 17 crops and 38 gizzards, averaging 0.3 cubic centimeter in each case. Feeding activity is greatest from approximately noon to 3:00 P.M. No competition for food occurs between Lace-necked and Barred Doves in Hawaii.
3. Either fresh or brackish surface water or succulent fruit is a prerequisite for good Lace-necked Dove range.
4. Lace-necked Doves may fly as far as 5 miles between roosting and feeding areas but favorable sites with both available food and good roosting cover have resident populations.
5. Roosting areas are usually densely wooded thickets along the coastal flats, occasional dense groves, or the peripheries of forested areas and wooded draws radiating therefrom, but some roosting occurs in practically any timbered area.
6. Lace-necked Doves breed mostly from February through September and pos-

sibly to a limited extent during the entire year.

7. The juvenile plumage lacks the black and white neck "lace" so characteristic of the adult and contour feathers are distinctly light tipped.
8. The sex ratio in 79 adult and nest-free juvenile doves was 43 males to 36 females or 119:100. Weights of 6 adults and measurements of 59 adults are given.
9. Lice externally and roundworms in the intestine, eye, and caecum occurred generally in light infestations. Tapeworm parasitism varied from light to extremely heavy.

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NOTES

Two Juvenile Pointed-tailed Ocean Sunfish, *Masturus lanceolatus,* from Hawaiian Waters

OSEPH E. KING[1]

The pointed-tailed ocean sunfish, *Masturus lanceolatus* (Liénard), is one of the "rare" marine fishes although it has been recorded from the tropical and subtropical areas of all oceans. In Gudger's review (1937*b*) of the natural history and distribution of the species, he reported only 59 authenticated records of the fish in the hundred years after its discovery in 1836. Strangely enough, of these 59 individuals there were 28 young and 31 adults, with no examples between the largest small specimen (60 mm. or 2.4 inches, standard length) and the smallest large specimen (30.5 inches, total length). Brimley (1939) has supplied records of five adult fish, ranging in size from 28 to 83 inches, that were not included in Gudger's report; four of these fish were from North Carolina waters, the fifth from Florida.

This wide gap between larval fish and adults was partially filled when three 6-inch juvenile fish were obtained from the stomach of a dolphin, *Coryphaena hippurus* L., taken in Florida waters (Gudger, 1938). Kuronuma (1940) described a juvenile *M. lanceolatus*, taken in a gill net in Japanese waters, which was 145 mm. in length from snout to caudal base and 259 mm. from snout to end of caudal fin. This interesting specimen differed from any previously described in that the caudal lobes was extended as a thin filament equal to approximately half the total body length.

Recently, Fitch (1950) reported that *M. lanceolatus* is found quite commonly in the stomachs of yellowfin tuna taken in Hawaiian waters, nearly a hundred specimens varying in size from ¼ inch to 2 inches having been obtained from this source. The only previous record of the species for Hawaiian waters is that of an adult fish, 37.3 inches in length, obtained from the Honolulu fish market in 1919 (Fowler, 1928).

The author has been unable to find in the literature any reports, except that of Kuronuma (1940), which describe or figure the caudal fin of *M. lanceolatus* as having more than a short lobe-like extension which may be pointed in the very young but in the adults is usually frayed or mutilated. From this characteristic shape of the caudal fin the fish has derived its scientific name, *Masturus lanceolatus* [Gr., *mastos*, breast or nipple; Gr., *oura*, tail; L., *lanceolatus*, a little lance = the nipple-tailed, lance-tailed fish (Gudger, 1937*a*)].

On April 11, 1950, during long-line fishing for tuna by the Fish and Wildlife Service research vessel *Hugh M. Smith*, a dolphin (1,100 mm. fork length) was taken just west of the island of Hawaii at 19° 30′ N. Lat.–156° 05′ W. Long. In the dolphin's stomach were two 5-inch *M. lanceolatus*, one in good condition, the other with a gash on each side. Both specimens (in alcohol) are generally similar in coloration to the 6-inch fish described by Gudger (1938). They are dark gray dorsally, shading into milky-white on the lower two-thirds of the body. They have the typical gray spotting below the eyes and pectoral fins and posteriorly above the anal fin.

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[1] Fishery Research Biologist, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, Honolulu, T. H. Manuscript received July 7, 1950.

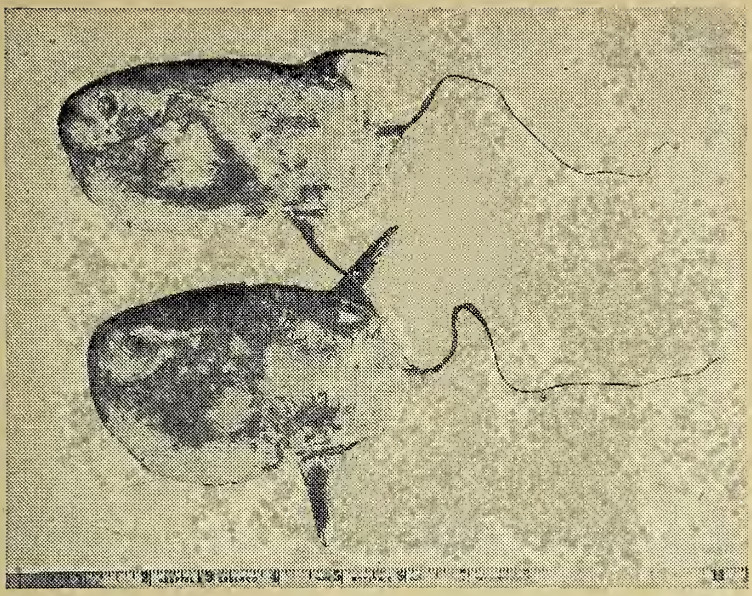

FIG. 1. Two juvenile *Masturus lanceolatus* taken from the stomach of a dolphin captured in Hawaiian waters. April 11, 1950.

These fish differ in one important respect, however, from any previously collected. Each has the caudal lobe continued as a whip-like structure longer than the body of the fish (Fig. 1). Except for the proximal 2 or 3 centimeters, this caudal extension is very fragile, almost paper-thin, and is frayed toward the tip. These may be the first observed specimens—at least among the post-larvae, juveniles, and adults—to show the true "normal" or unmutilated nature of the caudal fin. In view of the delicate structure of this appendage it is easily seen why the appendage is usually greatly reduced or missing in juvenile and adult specimens.

Measurements of the two fish, fin ray counts, etc., are given in the accompanying table:

REFERENCES

BRIMLEY, H. H. 1939. The ocean sun-fishes on the North Carolina coast. The pointed-tailed *Masturus lanceolatus* and the round-tailed *Mola mola*. *Jour. Elisha Mitchell Sci. Soc.* 55(2): 295–303.

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GUDGER, E. W. 1937*a*. The structure and development of the pointed tail of the ocean sunfish, *Masturus lanceolatus*. *Ann. and Mag. Nat. Hist.* XIX (10): 1–46.

——— 1937*b*. The natural history and geographical distribution of the pointed-tailed ocean sunfish (*Masturus lanceolatus*) with notes on the shape of the tail. *Zool. Soc. London, Proc.* Ser. A, Pt. 3, 353–396.

——— 1938. Three six-inch pointed-tailed ocean sunfish, *Masturus lanceolatus*, the largest post-larvae on record. *Jour. Elisha Mitchell Sci. Soc.* 55(2): 305–313.

KURONUMA, KATSUZO. 1940. A young ocean sunfish, *Mola mola*, taken from the stomach of *Germo germo*, and a specimen of *Masturus lanceolatus* as the second record from Japanese water. *Biogeogr. Soc. Japan, Bul.* 10(2): 25–28.

TABLE 1

MEASUREMENTS AND FIN-RAY COUNTS OF TWO JUVENILE POINTED-TAILED OCEAN SUNFISH (LENGTH AND DEPTH IN MILLIMETERS)

SPECIMEN	LENGTH TO			DEPTH			FIN-RAY COUNT				
	Base C	Edge C	Tip C	Behind eye	Before D & A	Over D & A	P	D	C	A	D+C+A
Good condition	111.9	135.0	300	59.8	63.6	121	10	20 (19?)	5+6+8	19 (18?)	58
Gashes in both sides	107.2	129.0	317	68.2	68.6	135	10	19 (18?)	5+6+7	18	55

News Notes

A new edition of Utinomi's *Bibliographia Micronesica* is to be published soon by the University of Hawaii Press. The extensive bibliography, which is the most complete list yet compiled of references to scientific publications concerned with Micronesia, was first brought out by Dr. Huzio Utinomi in Tokyo in 1944. It attempted to include all papers published until that time in the Micronesian aspects of the various fields of botany, zoology, geology, geophysics, anthropology and ethnology (including geography and fisheries). It is therefore a polyglot publication, citing not only papers published in the major European languages but also the contributions of Japanese scientists published in Japanese.

Almost all the copies of the original edition were destroyed during the bombing of Tokyo in the last months of World War II, and the few surviving copies have become, quite literally, museum pieces.

The chordate section of the bibliography was published in Volume I, Number 3, of *Pacific Science,* the plan then being to run a portion of the bibliography in succeeding issues of the journal. When this plan proved unfeasible, the University of Hawaii Press, at the request of *Pacific Science* editors, agreed to publish the complete work.

Members of the University of Hawaii faculty have cooperated in translating into English the Japanese citations, helping to make available for the first time to Occidental scientists references to papers which otherwise might remain unknown to them because of their lack of knowledge of Japanese ideographs.

The task of achieving correct translations was eased considerably by Japanese-speaking students and scholars at the University of Hawaii and by Dr. Utinomi, himself, in Japan. With their help the titles of the cited papers and publications have been translated into English, and the names of the journals, books, and other sources in which they appear have been translated into English and transliterated into the Romanji equivalents of the Japanese characters.

The citations in other languages remain in their original form. To complete the usefulness of the bibliography, the lists of the journals, magazines, and other publications in which the various citations appear are also provided, as they are in the original edition, in two sections, one composed of publications issued in Japan, primarily in the Japanese language, the other made up of publications in the languages of the Occident.

The University of Hawaii Press edition of Utinomi's bibliography will be published at $2.50 under the title *A Bibliography of Micronesia.* It will contain approximately 150 pages, and will present the citations in a double-column format designed for the convenience of the user. A prepublication price of $2.00 will apply on all orders received prior to May 1, 1951, the tentative publication date. Copies may be ordered from the University of Hawaii Press, University of Hawaii, Honolulu 14, Hawaii, U.S.A.

KUENEN, PH. H. *Marine Geology.* viii + 568 pp., 2 pls., 246 figs. John Wiley & Sons, Inc., New York, and Chapman & Hall, Limited, London, 1950. $7.50.

Marine Geology, by Ph. H. Kuenen, Professor of Geology, University of Groningen, The Netherlands, is a very welcome textbook summary in a field where progress has been laborious and slow. Despite the chief reliance of the geologic time scale on marine stratigraphy, treatment of marine processes in most textbooks has been almost necessarily meager. Elementary geology, in America at least, has been taught largely to students who have scarcely seen the sea. Oceanographic knowledge has been gathered mostly by workers in physics, chemistry, and biology and unhappily lodged in massive expedition volumes. Great numbers of geologists have only become aware of the ocean and its problems while engaged in often unrelated work during the Pacific War.

Professor Kuenen's treatise first combines the noun "geology" with the adjective "marine." Substantial parts of the data used are common to *The Oceans* of Sverdrup, Fleming, and Johnson and to *Submarine Geology* by Shepard, but in the aim and mode of treatment there is no significant overlap. Numerous tables and diagrams present a wealth of quantitative material from widely scattered sources, and the reader is impressed by the inclusion of published data up to 1948. One of the chief merits of the book is the degree to which presentation of basic data is followed through by analysis of many of geology's much-discussed questions such as the one of permanency of ocean basins. The book is very effectively illustrated; despite the profuse and not always discriminate use of halftones in the textbooks of the past half century, Kuenen has produced an altogether pleasing text without them.—C.K.W.

The following publications of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, Tokyo, Japan, have been received. Each report includes a list of all the reports previously published, their distribution, and rules for obtaining them.

Whiteware Raw Material Resources of Japan. [By Donald E. Lee and Hideshiro Hasegawa.] Report No. 135. 61 pp., 19 figs., 57 tables.

The Japanese Village in Transition. [By Arthur F. Raper, Tamie Tsuchiyama, Herbert Passin, and David L. Sills.] Report No. 136. 272 pp., 50 figs., 38 tables, numerous photographs.

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CRAWFORD, DAVID L. 1920*a*. New or interesting Psyllidae of the Pacific Coast (Homop.). *Ent. News* 31 (1): 12–14.

——— 1920*b*. Cerotrioza (Psyllidae, Homoptera). *Hawaii. Ent. Soc., Proc.* 4 (2): 374–375.

ROCK, JOSEPH F. 1916. The sandalwoods of Hawaii; a revision of the Hawaiian species of the genus *Santalum. Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry Bot. Bul.* 3: 1–43, 13 pls.

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PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL
AND PHYSICAL SCIENCES OF THE PACIFIC REGION

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Pacific Science, a quarterly publication of the University of Hawaii, appears in January, April, July, and October. Subscription price is three dollars a year; single copies are one dollar. Check or money order payable to University of Hawaii should be sent to Pacific Science, Office of Publications, University of Hawaii, Honolulu 14, Hawaii. Reprints of articles from Volumes I and II are available to subscribers.

MAY 24 1951

The Krauss Collection of Australian Fruit Flies (Tephritidae–Diptera)[1]

D. Elmo Hardy[2]

The following report deals with the fruit flies collected in Australia by N. L. H. Krauss of the Territorial Board of Agriculture and Forestry, Honolulu, T. H. This collection was made in conjunction with the studies which Mr. Krauss carried on in Australia concerning the biological control of fruit flies. It apparently represents the most comprehensive survey of the Australian fruit fly fauna which has been made (or at least reported in the literature). The collection contained approximately 60,000 specimens, and, although the studies were conducted largely in Queensland, it included almost all of the known Australian Dacini as well as a good representation of the other fruit flies. The collection, which contained 32 species and 3 varieties, includes all of the Australian Dacinae known to the writer except *Dacus* (*Strumeta*) *bancrofti* (Tryon), *D.* (*Strumeta*) *strigatus* (Perkins), *D.* (*Neodacus*) *newmani* (Perkins), *D.* (*Zeugodacus*) *atrisetosus* (Perkins), *D.* (*Zeugodacus*) *caudatus* Fabricius (?), and *Callantra aequalis* (Coquillett).

The basing of genera upon single chaetotaxic characters and upon secondary sexual characters does not appear to be a sound practice. Unless supported by other characters of generic value, these complexes should probably be considered as subgenera. I am preparing a reclassification of the Dacini of the world based upon a comparative study of many thousands of specimens, including genotypic specimens of nearly all of the "genera," and I am convinced that the classification could be placed on a more sound basis by treating most of these groups as subgenera of *Dacus* sens. lat. When large series of specimens are studied, intergrades between the various so-called "genera" are so often encountered that they completely break down the classification schemes of some of the contemporary and earlier workers. A detailed discussion of the value of these characters will be given in the reclassification study now being prepared. The subgeneric characters are discussed in their proper sequence in the text, but these characters are not repeated in the specific descriptions.

In the descriptions the length of the front is measured from the top of the ocellar triangle to the antennae, and the width is measured at its widest point. Evidently some other authors have measured the length as from the lower ocellus to the top of the lunule. It is probable that a more accurate comparison of the breadth of the front could be made by comparing it with the eye width or possibly with the width of the ocellar triangle. In some species the broadening of the front is accompanied by a lengthening so that a comparison of the width and the length is of little value. The first antennal segment is measured as seen in dorsal view from base to apex. The second segment is measured on the lower margin as seen in direct lateral view. The third segment is measured on the ventral margin as seen in direct side view. The facial spots, or markings, are of value in the classification of these flies, but considerable variation does occur and supporting characters must be relied upon. The markings and coloration of the thorax and abdomen are fairly constant for specimens of the same age (before killing). Much variation in coloration does occur, but it appears to be very closely associated with the tenerality of the specimen.

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[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 214. In cooperation with the Oriental Fruit Fly Investigations, U. S. Bureau of Entomology and Plant Quarantine. Manuscript received August 29, 1950.

[2] Associate Entomologist, University of Hawaii Agricultural Experiment Station, Honolulu, T. H.

The nomenclature used for the wing venation is that of Comstock-Needham (Comstock, 1918) as emended by Tillyard (1919) and Alexander (1927; 1929). I have used this terminology in other papers on the Tephritidae and various other families of Diptera. Following this system, vein R_2 is considered as being fused with R_1; vein R_3 is considered a simple vein; R_4 and R_5 are fused; M_1 and M_2 are fused as are M_3 and M_4; the large crossvein is the m; the portion which was formerly called the base of Cu_1 is now considered to be the m–cu crossvein; the anal cell of other writers is considered to be the cubital cell, and the vein extending from the apex of this cell is Cu_1+1st A, not Cu_2+2d A. In the descriptions the length of the narrowed portion of the cubital cell is compared to the length of the free portion of Cu_1+1st A. This refers to that portion of the wing from the apex of cell Cu to the margin. Often the vein itself will evanesce or become very faint and in some species may not reach the wing margin.

The female ovipositors have been found to be of great taxonomic importance. By comparing the size, shape, and structural details, the distinguishing of species is greatly facilitated. To study these structures it is necessary that they be mounted on microscope slides and examined at magnifications of 150 times or more. The basal segment of the ovipositor (the oviscape of Munro, 1947) is usually the most conspicuous portion of the ovipositor in unmounted specimens. It is the seventh abdominal segment and bears a pair of spiracles. The position of these spiracles appears to be of taxonomic importance in some species. The distance of the spiracles from the base of the segment is measured to the posterior lateral margins, not to the base of the convex margin of the venter. The inversion membrane is the membranous middle segment of the ovipositor which bears the rasper. This is considered to be the modified eighth abdominal segment. The arrangement of the scales or stout setae on this segment is of taxonomic importance, especially the comparative approximation of the scales of the rasper to the base of the segment. The piercer is the apical segment of the ovipositor and is called the aculeus by some writers. It is distinctive in shape and is most useful in distinguishing species. The breadth of the segments which make up the ovipositor is measured at the widest points. The measurements of the bodies given in the descriptions do not include the ovipositor or the antennae.

All of the rearings are from the fruits of the various indicated hosts. The wording "ex such and such host" should be interpreted to mean the fruit of that host. Except for a few specimens which Mr. Krauss obtained from C. P. Hely, all the material covered in this report was collected by N. L. H. Krauss.

Acknowledgments: I am greatly indebted to Mr. Krauss for his wholehearted interest and cooperation in making such a thorough survey of the Australian Dacini. He is a most capable and energetic collector, and his efforts have given us a wealth of valuable information on the Australian fruit flies. I am also grateful to Mr. Alan May, Department of Agriculture and Stock, Toowoomba, Queensland, for supplying information on, and representatives of, the Queensland species described by Perkins and May, and to Mr. Jos. E. Collin, Newmarket, England, for providing information on Macquart's type of *Urophora bicolor*. The drawings have been prepared by Miss Marian Adachi, University of Hawaii, and the preparatory work on this collection and a large share of the bibliographical details of this study were very efficiently handled by Betty Lou Defibaugh, United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, Honolulu. Their able assistance is much appreciated, for their efforts have added greatly to the completeness of this paper.

DACUS Fabricius sens. lat.

Dacus Fabricius 1805. Syst. Antl. p. 272.
Tridacus Bezzi 1915. Bul. Ent. Res. 6: 88.

In a broad sense the genus *Dacus* includes those Dacini which possess the following combination of characters: no complete suture across the mesonotum; no strong spines on the front femora; the second portion of vein M_{1+2} not bent downward; cell 1st M_2 not strongly narrowed behind the r–m crossvein; the abdomen not petiolated and the antennae not greatly elongated; the third segment not much longer than the face, and the antennae not two or more times longer than the face. All of the Australian Dacini, with the possible exception of *Callantra aequalis* (Coquillett), are treated as *Dacus* sens. lat. by this writer.

GENOTYPE: *Dacus armatus* Fabricius.

KEY TO THE SUBGENERA OF *Dacus* (SENS. LAT.) KNOWN TO OCCUR IN AUSTRALIA[3]

1. Scutellum with four strong bristles . . 8
   Scutellum with two bristles 2
2. Prescutellar bristles absent 3
   Prescutellars present 5
3. Anterior supra-alar bristles absent . . . 4
   One pair of anterior supra-alars present . . . . *Neodacus* Perkins
4. Crossvein r–m situated below the middle of cell 1st M_2 (discal cell) and distinctly before the apex of vein R_{1+2}; three to four pairs of inferior fronto-orbital bristles present . . . . *Heterodaculus* n. subgen.
   Crossvein r–m beyond the middle of 1st M_2 and about opposite the end of vein R_{1+2}; two pairs of inferior fronto-orbitals present. *Daculus* Speiser
5. Anterior supra-alar bristles present . . . 6
   Anterior supra-alar bristles absent . . . . *Afrodacus* Bezzi
6. Third tergum of male with a row of cilia on each side . . . *Strumeta* Walker
   Third tergum of male not ciliated . . . 7
7. Male wing with a well-developed supernumerary lobe (at apex of vein Cu_1+1stA) . . . . *Asiadacus* Perkins[4]
   No distinct supernumerary lobe in male wing . . . . *Gymnodacus* Munro
8. Prescutellar bristles present 9
   No prescutellar bristles . . . . *Austrodacus* Perkins
9. Third tergum of male ciliated 10
   No cilia on sides of third tergum of male 11
10. No anterior supra-alar bristles present; supernumerary lobe not developed in male wing. *Hemizeugodacus* n. subgen.
    Anterior supra-alar bristles present; supernumerary lobe well developed in male wing . . . . . . *Zeugodacus* Hendel
11. Supernumerary lobe present in male wing . . . . *Melanodacus* Perkins
    No supernumerary lobe in male wing . . . . *Paratridacus* Shiraki

DACUS (AFRODACUS) Bezzi

Afrodacus Bezzi 1924. Ann. S. Afr. Mus. 19: 452.

This subgenus is characterized by the absence of the anterior supra-alar bristles. In other respects it is like the subgenus *Strumeta*. The group occupies a borderline position between *Strumeta* and *Daculus*. Specimens of *D.* (*Afrodacus*) *jarvisi* (Tryon) have been studied which have a well-developed anterior supra-alar bristle on one side of the mesonotum. These would occupy a position halfway between *Afrodacus* and *Strumeta*. Some aberrant specimens of *D.* (*Daculus*) *murrayi*

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[3] *Callantra* Walker has not been treated here since it was not represented in the Krauss collection. Its exact position is not clearly understood at the present time. The typical species of *Callantra* are very characteristic and certainly appear to be generically distinct from *Dacus*. There are, however, borderline species which may link these two groups very closely.

[4] Not known to occur in Australia. It is included here because of a difference of interpretation of writers. Perkins and May (1949) recently described *Asiadacus calophylli*. I have treated this in the subgenus *Gymnodacus*.

(Perkins) have definite prescutellar bristles in varying stages of development. Many specimens of this species which have the characters of *Afrodacus* have been studied. The typical forms fall into *Daculus*.

GENOTYPE: *Afrodacus biguttulus* (Bezzi)

KEY TO KNOWN SPECIES OF *Dacus* (*Afrodacus*) OF THE PACIFIC REGION

1. Wings with infuscations along either the r–m or the m crossveins 2
   Wings without infuscations on the crossveins 3
2. Posterior two-thirds of the scutellum brown; r–m crossvein infuscated; indistinct facial spots present (Australia) . . . . *brunneus* (Perkins and May)
   Scutellum yellow, except for a narrow basal band of black; m crossvein infuscated, r–m hyaline; face with a transverse black band (Java) . . . . *javanensis* (Perkins)
3. Humeri and notopleural calli not joined by a yellow band 4
   Humeri and notopleural calli joined by a broad yellow band; scutellum yellow, distinctly paler than the mesonotum . . . . *jarvisi* (Tryon) 3a
   3a. Halteres yellow; squamae and fringes white; the anterior notopleural bristles are located within the confines of the yellow band connecting the humeri and notopleural calli . . . . *jarvisi jarvisi* (Tryon)
   Halteres reddish-brown; squamae and fringes yellow; anterior notopleural bristles on a reddish-brown ground color. . . . . . . *jarvisi* var. *halteratus* (Hendel)
4. Mesonotum chiefly brownish-yellow, without black markings; scutellum brownish-yellow, darker on the sides; cubital streak narrow and faint; in the female ,vein $Cu_1 +$ 1st A from the apex of the cubital cell to the wing margin is about one and one-half times longer than the narrowed portion of the cubital cell (Samoa) . . . . *aenigmaticus* Malloch
   Mesonotum conspicuously marked with black (Fig. 1*a*); scutellum yellow; cubital streak broad and distinct; in the female, the section beyond the apex of the cubital cell is shorter than the narrowed portion of the cell . . . . *aberrans* n. sp.

Dacus (Afrodacus) aberrans n. sp.

Fig. 1*a–c*

This species appears to be more closely related to *D. aenigmaticus* Malloch than to any other known species. It is differentiated by the largely black mesonotum, by the more elongate cubital cell in the wing, by the abdomen lacking black markings on the sides of segments 3 to 5, and by the scutellum being yellow, much paler in color than the mesonotum.

MALE. A moderately small species predominantly reddish in color except for the black median portion of the mesonotum. *Head:* Rufous except for the facial spots and the ocellar triangle. The head bristles are all black. There are two pairs of inferior fronto-orbitals. The front is nearly parallel sided, and it is one and one-half times longer than wide. There are no dark spots at the bases of the bristles and the tumescence is dark reddish, faintly discolored with a brownish hue. The facial spots are oval and are spaced about three-fourths of their length from the oral margin; the spots are about one-fourth as long as the face. The third antennal segment is slightly brownish, is three times longer than wide, and is just slightly longer than the face. *Thorax:* The hind portion of the mesonotum is extensively black. This black area extends laterally almost to the inner supra-alar bristles and anteriorly to a point opposite the position occupied in other subgenera by the anterior supra-alar bristles (Fig. 1*a*). Beyond this point the black pattern breaks down into three vittae—one median and two sublateral—which extend to the front margin of the mesonotum. The sublateral black vittae are inter-

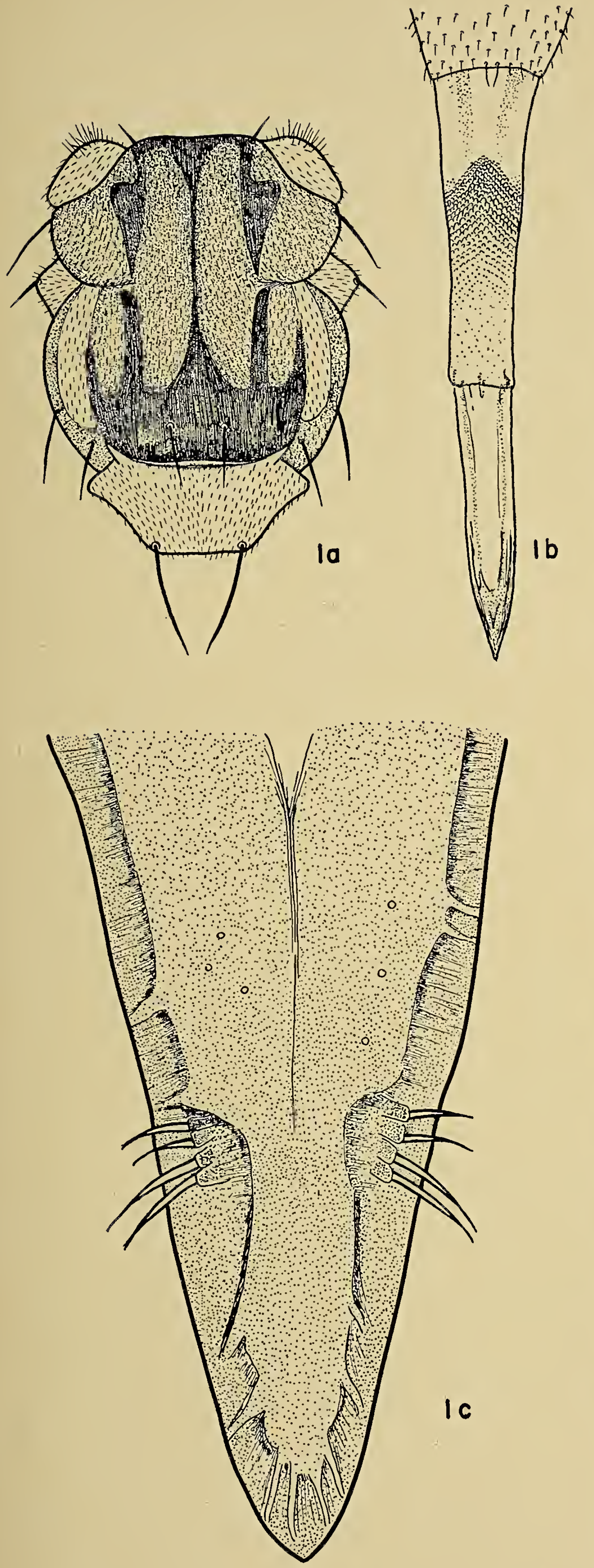

FIG. 1. *Dacus* (*Afrodacus*) *aberrans* n. sp.: a, thorax, dorsal view; b, female ovipositor, full length; c, ovipositor, apex.

rupted slightly at the suture. The median vitta is expanded on the anterior part of the mesonotum. In some specimens the black coloring broadly covers the front portion of the dorsum, occupying much of the medial part beyond the suture. In others it forms just a T-shaped pattern behind the bases of the scapular bristles. The area of the mesonotum between and outside the black markings, excepting the lateral yellow stripes, is reddish in color and densely gray pollinose. The yellow stripes are very short; they do not extend to the inner supra-alar bristles. The scutellum is all yellow except for a very narrow black band across its base. The pleura are yellow to rufous, except for the predominantly black sternopleura and for a black spot on the front of the mesopleura and sternopleura, a spot on the hypopleura, and one on the lower margin of the metapleura. The metanotum is black except for a red spot in the central portion. The vertical yellow stripe on the mesopleura is expanded on the dorsal portion and extends anteriorly to a point opposite the anterior notopleural bristles. *Legs:* Yellow, except for the brownish hind tibiae. *Wings:* First two costal cells hyaline, devoid of microtrichia except in the apex of the second cell. Costal band distinct, brownish, not extending noticeably below vein R$_3$ except along the wing margin. The band is not expanded in the apex and extends halfway through cell R$_5$. The r–m crossvein is straight and nearly vertical in position. It is situated distinctly beyond the middle of cell 1st M$_2$. The cubital streak is broad, filling all of the basal portion of cell M$_4$ and extending nearly to the top margin of the m–cu crossvein. The narrowed portion of the cubital cell is two and one-half times longer than the portion from the apex of the cell to the wing margin. *Abdomen:* Nearly all reddish except for a black vitta extending down the middle of terga 3 to 5. The base of the third tergum possesses a narrow black crossband in some specimens but is brownish in others. The first tergum is brownish on the basal portion and yellow-red apically. The second tergum has a subbasal brown to slightly blackish crossband and a yellow-white apex. In some specimens the median black vitta is indistinct on terga 3 and 4.

Length: Body, 5.5–5.8 mm.; wings, 4.8–5.0 mm.

FEMALE. The hind tibiae often have a blackish tinge on their apical halves. The narrowed portion of the discal cell is one and one-fifth times longer than the portion beyond the apex of the cell. *Ovipositor:* Short and inconspicuous; the exposed portion is not as long as the fifth abdominal segment. The extended ovipositor is very short and comparatively broad (Fig. 1*b*), the over-all length is about 3.3 mm. The piercer measures approximately 1.08 mm. by 0.24 mm. The oviduct extends to within 0.19 mm. of the apex of the piercer and the setae are about 0.06 mm. from the apex. The setae and the plate bearing them are rather short, the length of the plate, or the length of the longest setae, being equal to about one-fourth the distance from the bases of the distal pair of setae to the apex of the piercer (Fig. 1*c*). The inversion membrane is about 1.2 mm. long by 0.3 mm. wide. The scales of the rasper are broad and blunt and extend to within 0.3 mm. of the base of the eighth segment. The basal segment of the ovipositor is about 1.0 mm. long by 1.0 mm. wide, the spiracles are situated approximately 0.22 mm. from the posterior lateral margins of the segment.

Holotype male, allotype female, and eight paratypes (three males and five females): Lake Barrine, Queensland, ex *Litsea* (?), Nov., 1949.

Type and allotype deposited in the United States National Museum. Two paratypes in the Bishop Museum; two in the Territorial Board of Agriculture and Forestry collection; two in the Hawaiian Sugar Planters' Association collection; and two at the University of Hawaii.

Dacus (Afrodacus) jarvisi (Tryon)

Fig. 2*a*, *b*

Chaetodacus jarvisi Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 201–203.

Dacus (*Chaetodacus*) *australis* Hendel 1928. Ent. Mitteil. 17(5): 341–342. New synonymy based upon a careful comparison with the original description and confirmed by Dr. M. Hering, who compared specimens of *jarvisi* with paratypes of *australis*.

This species is readily distinguished from all known members of this subgenus by the continuous yellow markings connecting the humeral and notopleural calli. Only the more important characteristics are given in the following description.

MALE. Front very slightly expanded on the lower half, nearly two times longer than wide. The vertical bristles are brownish-yellow to yellow, the frontals are brown to black. Two pairs of inferior fronto-orbital bristles are present. The facial spots are nearly circular and their height is equal to about one-fourth the length of the face. The third antennal segment is just slightly longer than the face and is appoximately three times longer than wide. *Thorax:* Chiefly reddish, mesonotum largely gray pollinose. The gray pollen is dissected by one median and two sublateral shining lines extending the full length of the dorsum. *Wings:* First two costal cells hyaline with no microtrichia except in the apex of the second cell. The costal band is rather narrow and does not extend below vein R_3 except at its base and extreme apex. The band expands slightly in the wing apex and extends nearly halfway between the ends of vein R_{4+5} and M_{1+2}. The cubital streak is broad, filling all of the base of cell M_4 and extending nearly to the top margin of the r–m crossvein. The narrowed portion of the cubital cell is about three times longer than the distance from the apex of the cell to the wing margin. *Abdomen:* Chiefly yellow to rufous. First tergum all yellowish, sometimes faintly brownish tinged. Second tergum with a subbasal brown to

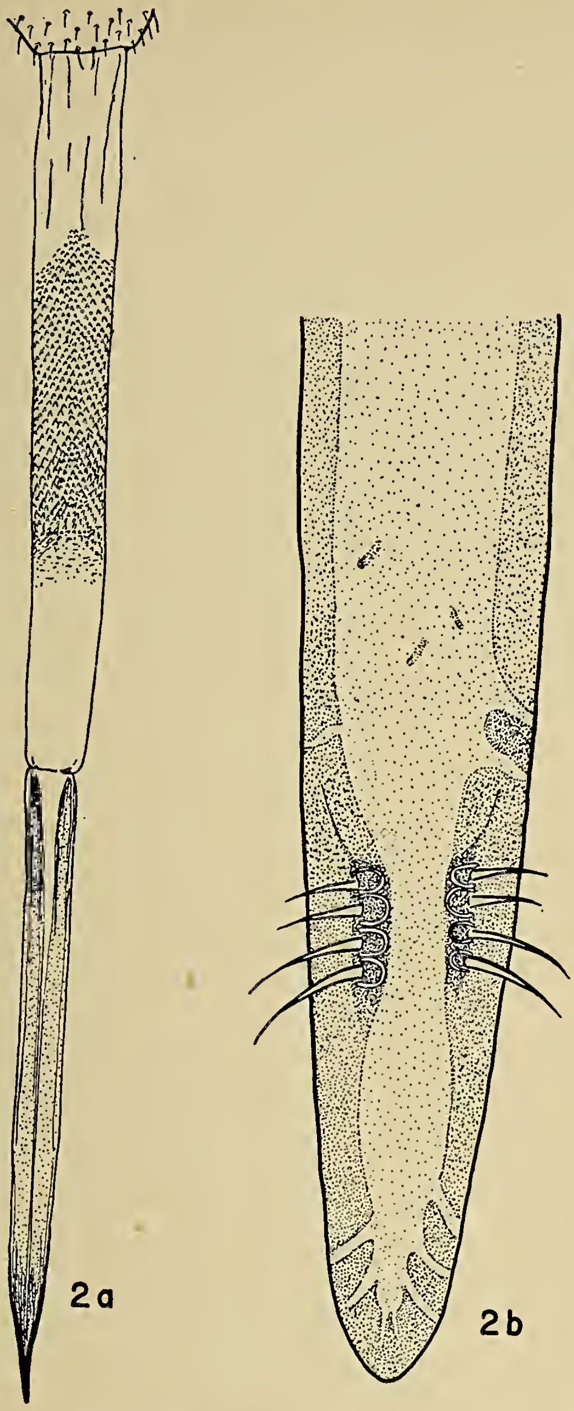

FIG. 2. *Dacus* (*Afrodacus*) *jarvisi* (Tryon): a, female ovipositor, full length; b, ovipositor, apex.

black band; the apical half is whitish-yellow. The third tergum has a narrow black band across its base and a narrow black line running longitudinally down the middle. The black median vitta continues on over terga 4 and 5.

Length: Body, 6.5–7.0 mm.; wings, 6.0–6.5 mm.

FEMALE. The narrowed portion of cell Cu is slightly more than one and one-half times longer than the distance from its apex to the wing margin. *Ovipositor:* The exposed portion is about equal in length to the combined lengths of segments 4 and 5. The extended ovipositor (Fig. 2*a*) measures about 5.0 mm. in length. The piercer (Fig. 2*b*) is approximately 1.7 mm. long by 0.22 mm. wide. The oviduct extends to within 0.23 mm. of the apex of the piercer. The setae are about 0.05 mm. from the apex, this distance being equal to about two times the length of the plate bearing the setae or to two times the lengths of the longest setae. The inversion membrane is about 2.0 mm. in length by 0.3 mm. in width. The scales of the rasper extend to within 0.6 mm. of the base of segment 8. The basal segment of the ovipositor is about 1.4 mm. long by 1.2 mm. wide. The spiracles are located 0.28 mm. from the posterior-lateral margins of the segment.

TYPE LOCALITY: Stanthorpe, South Queensland; reared from pear and quince.

Type in Queensland Museum.

Large numbers of specimens were in the Krauss collection from the following: Cairns, Queensland, ex papaya, *Eugenia cormiflora*, *Semecarpus australiensis*, guava, *Careya australis*, and *Terminalis catappa*, Dec., 1949, to Apr., 1950.

Dacus (Afrodacus) jarvisi var. halteratus Hendel

Dacus (*Chaetodacus*) *australis* var. *halterata* Hendel 1928. Ent. Mitteil., 17(5): 342-343.

This variety was not present in the Krauss collection but because so much material has been studied from the Cairns area its status should be discussed here. The variety *halteratus* was described from a single female specimen taken at Cairns. Dr. Hering (in correspondence) said that he had studied the type of "*halterata*" years ago and that it "is only an individual form" of *jarvisi*. It is probable that this should not be considered a variety but should be treated as a synonym. Of the large number of specimens of *jarvisi* which have been studied from the Cairns area none has been seen which fits the description of *halteratus*. Hendel's specimen was probably discolored. According to the original description and Dr. Hering, the variety differs from the typical form by having the halteres reddish-brown with brown knobs, the squamae and their fringe yellow, and the anterior notopleural bristles situated on a reddish-brown ground color. The anterior notopleural bristles in typical *jarvisi* are located near the outer edge of the yellow band. There is obviously some variation in this character, and in many specimens the bristle will be placed just outside the confines of the yellow coloring.

TYPE LOCALITY: Cairns, Queensland.

Type in the Deutsches Entomologisches Institut, Berlin.

DACUS (ASIADACUS) Perkins

Asiadacus Perkins 1937. Roy. Soc. Queensland, Proc. 48(9): 57.

This subgenus was not represented in the Krauss collection from Australia but because one of the species, *Dacus* (*Gymnodacus*) *calophylli* (Perkins and May), was recently described as an *Asiadacus*, a discussion of this group is pertinent to this paper.

The group differs from *Dacus* (*Strumeta*) in lacking the cilia on the third tergum of the male. It is very close to *Gymnodacus* (see discussion under *Gymnodacus*) and is separated only by the presence of a supernumerary lobe in the wings of the males. The subgenus is poorly defined, and it is questionable whether or not the presence or absence (or degree of development) of the supernumerary lobe has even subgeneric importance in this case.

GENOTYPE: *Chaetodacus bakeri* Bezzi.

KEY TO KNOWN SPECIES OF *Asiadacus*

1. Wings with a very large apical spot which fills all of the apex and extends to vein M_{1+2}; no median yellow stripe on the mesonotum (Philippine Islands) . . . . *bakeri* (Bezzi)

   Wings with no well-developed apical spot; mesonotum with a median yellow stripe (Ceylon, India) . . . . *diversus* (Coquillett)

DACUS (AUSTRODACUS) Perkins

Austrodacus Perkins 1937. Roy. Soc. Queensland, Proc. 48: 56.

The members of this subgenus are characterized by having four scutellar bristles and no prescutellar and anterior supra-alar bristles. The males have no cilia on the third abdominal tergum and no well-developed supernumerary lobe in the wings. The group is more distinctively set off than are most of the subgenera of *Dacus*, but there are some borderline characteristics present. In some specimens the mesonotal hairs, in the position where prescutellar bristles normally arise, are more strongly developed than the surrounding setae; they are erect, two to three times longer than the other setae, and they have the appearance of being rudimentary prescutellar bristles. The secondary pair of scutellar bristles is sometimes comparatively weak and shows definite intergrading in size. The supernumerary lobe is partially developed in the male wing, occupying an intermediate position between those groups which have a well-developed lobe and those which have none.

GENOTYPE: *Dacus cucumis* French.

D. cucumis is the only known species in this subgenus.

Dacus (Austrodacus) cucumis French

Fig. 3*a–d*

Dacus tryoni var. *cucumis* French 1907. Dept. Agr. Victoria, Jour. 5: 307.

This species is easily recognized by the subgeneric characters listed above. It superficially resembles *Dacus* (*Hemizeugodacus*) *algaiae* n. sp. and *Dacus* (*Daculus*) *signatifer* Tryon. This resemblance is discussed under the description of the above-mentioned species.

MALE. Entirely yellow to rufous except for the black facial spots and some dark markings on the abdomen. *Head:* Front nearly two times longer than wide and clear reddish-

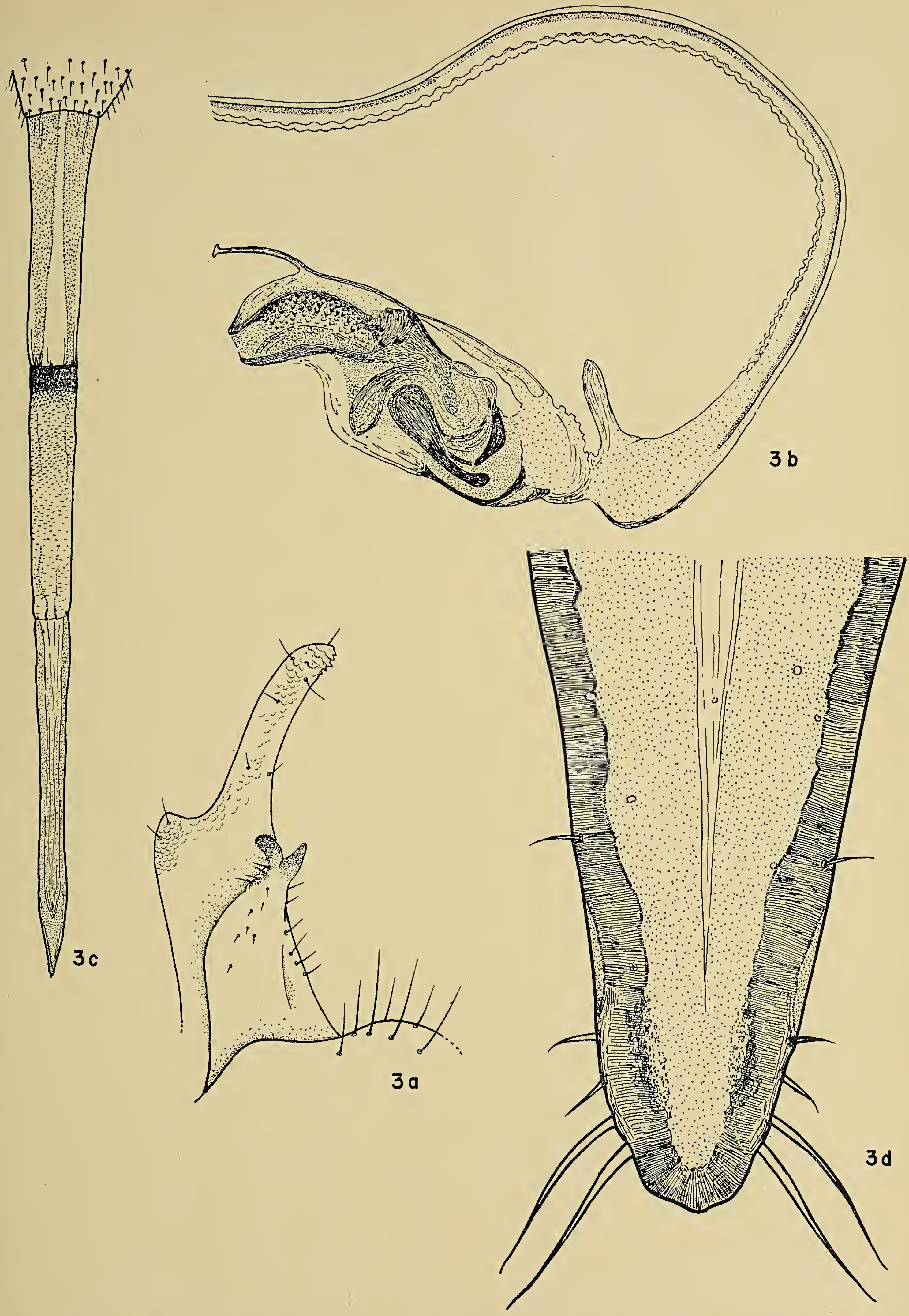

FIG. 3. *Dacus* (*Austrodacus*) *cucumis* French: a, apical lobes of ninth segment of male genitalia; b, apex of male aedeagus; c, female ovipositor, full length; d, apex of ovipositor.

yellow with no discolorations or spots except for a slight brownish marking which sometimes occurs in the central part. The vertical and frontal bristles are dark brown to black, the other head bristles and hairs are yellow. The third antennal segment is comparatively short and broad. It is approximately equal in length to the face and is slightly less than three times longer than wide. The facial spots are oval and their length is equal to about one-third the length of the face. *Thorax:* With three broad, yellow postsutural stripes. The yellow area on each mesopleuron broadens in the dorsal portion and covers almost all of the dorsal margin of that sclerite; the yellow markings of the mesopleura are separated from the humeri by a short space where the integument is rufous. *Legs:* Entirely pale colored, the femora whitish on their basal three-fourths and yellow at their apices. *Wings:* First two costal cells hyaline and devoid of microtrichia except in the apex of the second section. The costal band is very narrow and does not extend below vein R_3 except at its apex. The band extends around the wing margin beyond the apex of vein R_{4+5}. The cubital streak is pale yellow and is broad at its base but fades out just beyond the apex of the cubital cell. The streak occupies all of the basal part of cell M_4 and extends about half way along the m–cu crossvein. There is a distinct indication of a supernumerary lobe at the apex of vein $Cu_1 +$ 1st A but no well-developed lobe. The narrowed portion of the cubital cell is approximately equal to that section from the apex of the cell to the wing margin. *Abdomen:* First tergum brownish on the sides on basal half, second tergum with a brown subbasal band and a whitish apical band; abdomen otherwise rufous except for an elongate brown spot, or vitta, down the middle of the fifth tergum. *Genitalia:* The tenth segment is well developed and conspicuous. It is hollowed out, spoon-shaped in end view and convex below, and has strong yellow hairs on the venter and around the margins. The apical lobes of the ninth segment are long and slender and have five to six small teeth on the underside of the apex (Fig. 3*a*). A slight ridge or line extends across the apex from each of the teeth. A small secondary lobe is developed at the basal part of each of the long finger-like lobes; the integument of this lobe is microscopically reticulated. The inner basal lobes of the ninth segment have a pair of black, blunt processes at their apices. The aedeagus is distinctive. The apical sac-like portion has the inner walls covered with very stout spine-like processes (Fig. 3*b*). Those spines in the outer portion of the sac have serrated edges. The genital pore is dorsal and extends beyond the remainder of the aedeagus.

Length: Body, 6.0 mm.; wings, 5.6 mm.

FEMALE. The distance from the apex of the cubital cell to the wing margin is one and one-third times greater than the length of the narrowed portion of the cubital cell. *Ovipositor:* In *in situ* mounts the exposed ovipositor is almost as long as terga 4 and 5 combined. When extended the ovipositor is long and slender; when viewed under high power it is very characteristic in development. The over-all length (Fig. 3*c*) is about 6.4 mm. The piercer is approximately 1.7 mm. long by 0.2 mm. wide at its broadest point. The setae are strong and conspicuous and are situated almost at the apex of the piercer; the closest pair is about 0.02 mm. from the apex. The setae which are most distally placed extend well beyond the apex of the piercer. The apex of the piercer is blunt, undulated, and indistinctly trilobed (Fig. 3*d*). The apex of the oviduct is about 0.17 mm. from the tip of the piercer. The inversion membrane is approximately 2.2–2.4 mm. long by 0.3 mm. at its widest point. The scales of the rasper end about 1.1 mm. from the base of the eighth segment. The basal segment of the ovipositor is about 1.5 mm. long by 1.3 mm. at its widest point. The spiracles are situated about 0.17 mm. from the base of the segment measured on the lateral margins.

Length: Body, 6.0–7.0 mm.; wings, 5.5–6.2 mm.

TYPE LOCALITY: Bowen, Queensland.

Type in the Queensland Museum.

About two dozen specimens are in the Krauss collection from: Smithfield, near Cairns, Queensland, ex cucumber, June, 1949; and Ellis Beach, near Cairns, ex *Glochidion harveyanum*, Feb., 1950.

DACUS (DACULUS) Speiser

Daculus Speiser 1924. Beitr. Tierk. Konigsberg 140.

The subgenus *Daculus* is characterized by the absence of prescutellar and anterior supra-alar bristles. It is similar in most respects to *Dacus* (*Strumeta*). This group definitely occupies a borderline position and intergrades into related subgenera. Many specimens of *D. murrayi* which have distinct prescutellar bristles have been examined. Some of the abnormal individuals would have to be classified as *Afrodacus*. Other specimens possess just a single prescutellar bristle or rudiments of one or more of the bristles. Specimens of *D. signatifer* Tryon show definite intergrading toward *Austrodacus* because of the presence of rudimentary secondary scutellar bristles.

Two species of *Dacus* (*Daculus*) are now known from Australia. Both of these have been taken in the vicinity of Cairns, Queensland. There are no other known Australian records for this group.

GENOTYPE: *Dacus oleae* (Gmelin).

KEY TO AUSTRALIAN SPECIES OF *Dacus* (*Daculus*)

Mesonotum with three yellow vittae; abdomen without definite black bands or a black median vitta; costal band narrow, not extending beneath vein R_3 except at apex. . . *signatifer* Tryon

Mesonotum with just two yellow vittae; abdomen with a black basal band on segment 3 and a black median vitta down terga 3 to 5; costal band extending below vein R_3. . . . . *murrayi* (Perkins)

Dacus (Daculus) murrayi (Perkins)

Fig. 4*a–c*

Daculus murrayi Perkins 1939. Univ. of Queensland, Dept. Biol. 1 (10): 25–26.

This species is readily recognized from the other members of the subgenus by the absence of a median yellow vitta on the mesonotum, by the presence of a black median vitta on abdominal segments 3 to 5 as well as by the differences in wing coloration, the female ovipositor, the shape of the facial spots, and the general body coloring.

The species has been adequately described by Perkins (1939) and figured by Perkins and May (1949). Only the diagnostic characters, with the addition of wing characteristics and a description of the female ovipositor, are presented here.

MALE and FEMALE. A comparatively pale species, without dark markings except for the facial spots, the black marks on the abdomen, and the darkened tibiae of the hind legs. *Head*: The front is about two times longer than wide. The facial spots vary somewhat in size and shape, they are subcircular, and extend nearly to the oral margin. The front has two pairs of inferior fronto-orbital bristles. *Thorax*: Mesonotum chiefly reddish with a light tinge of brown in ground color. This is covered with grayish pruinosity except for the lateral yellow vittae and for three subshining lines extending the entire length of the dorsum. One of these lines is median in position, and the other two lie just inside the lateral yellow vittae. The original description states that "the median line and a line on the outer border of the hoary bands are dark brown." The series of specimens from Queensland show variation from distinctly brownish tinged to entirely rufous. *Legs*: Yellowish, the hind tibiae and the apical subsegments of the tarsi discolored with brown to black. *Wings*: First two sections of costa distinctly yellow-fumose but devoid of microtrichia except for the apical part of the second section and for a line of hairs along the extreme lower margin of these cells. The costal band is brown and extends just a short distance below vein R_3, terminating almost half way between the apex of vein R_{4+5} and the tip of M_{1+2}. The section of cell R just above cell M is yellow-fumose and densely covered with microtrichia; the section directly above the base of vein M_{3+4} is bright yellow. The cubital streak is yellow-brown and is moderately broad. It fills all of the basal portion of cell M_4, extending to the top margin of the m–cu crossvein. The yellowish coloration extends to about the apex of the cubital cell in the male and half the distance from the apex of the cubital cell to the wing margin in the female. Just above vein Cu_1+ 1st A is a dense clump of long dark gray to blackish hairs. Below this vein, filling the apical part of the 1st anal cell, is a dark gray to blackish spot produced by a great abundance of closely placed microtrichia in that portion of the wing. Vein Cu_1+1st A is over two times longer than the narrowed portion of the cubital cell in the female. It is just slightly longer than the r–m crossvein. In the male, vein Cu_1+1st A is distinctly less than half the length of the narrowed portion of cell Cu and is three-fourths as long as the r–m crossvein. The supernumerary lobe is distinct in the male. *Abdomen*: Chiefly rufous, with a black, longitudinal vitta down the middle of terga 3 to 5, a transverse band of black across the base of the third tergum and discolorations of brownish to black on the sides of terga 3 to 5. The second tergum also has a narrow brown to blackish basal band in some of the specimens. The males have a row of long black hairs on each side of the third tergum. *Ovipositor*: Comparatively long and conspicuous. In the average specimens the exposed portion of the ovipositor is equal in length to the last three abdominal segments. The basal segment of the ovipositor (segment 7), as seen from above, is one-third longer than the fifth tergum. When fully extended (Fig. 4*a*) the ovipositor, including the basal segment, measures approximately 6.8 mm. in length. The piercer (aculeus) is 2.1 mm. long by 0.14 mm. wide at its widest point. The piercer is gradually tapered beyond the apex of the oviduct into a slender point and possesses four pairs of subapical setae. The two pairs nearest the apex are two times longer than the more basally situated

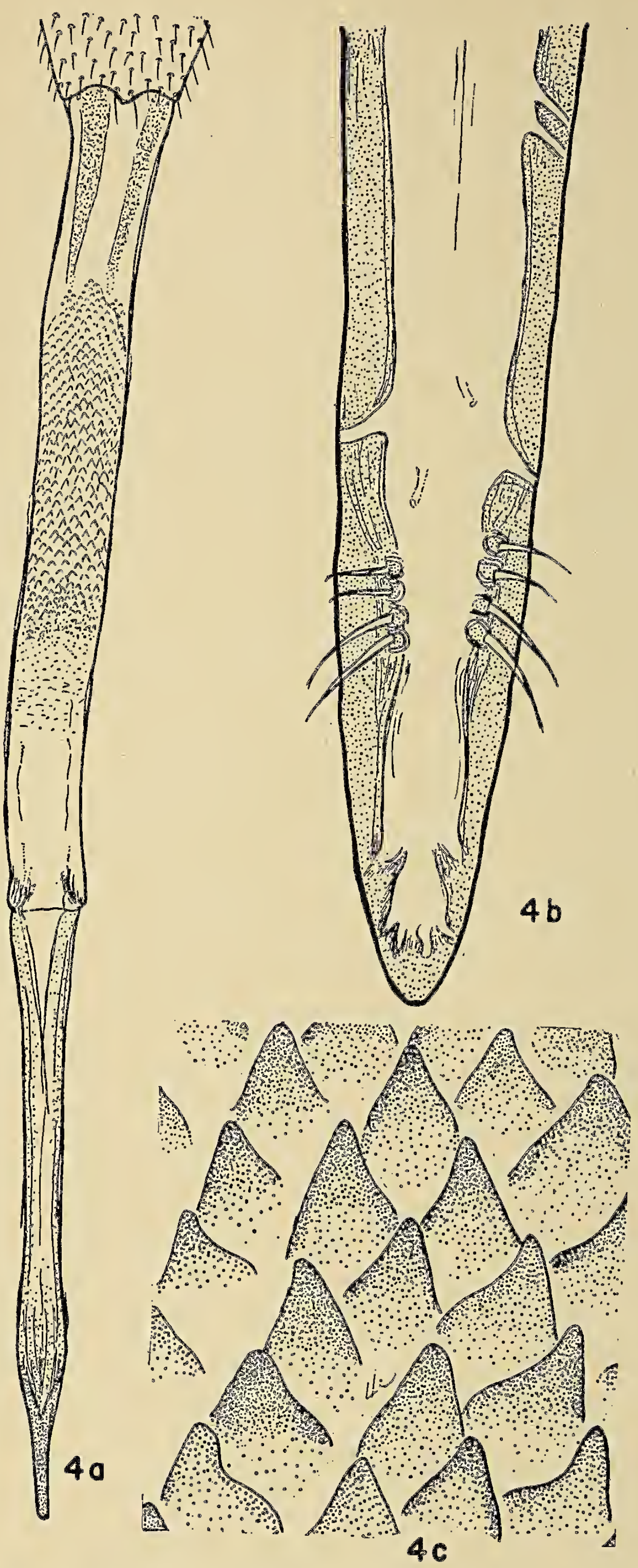

FIG. 4. *Dacus* (*Daculus*) *murrayi* (Perkins): a, female ovipositor, full length; b, apex of ovipositor; c, scales of the rasper.

pairs. The distance between the tip of the ovipositor and the first pair of setae is four times greater than the length of these setae. The apex of the oviduct is about 0.38 mm. from the tip of the piercer (Fig. 4*b*). The inversion membrane (segment 8) is 2.8 mm. long by 0.28 mm. wide at its broadest point. The rasper extends to about 0.61 mm. from the base of the segment. The hook-like processes of the rasper are rather long-pointed (Fig. 4*c*). The basal segment of the ovipositor (oviscape or segment 7) is 1.9 mm. long by 1.22 mm. wide measured at its base. The spiracles are situated about 0.38 mm. from the base of the seventh segment, measured on the lateral margins.

Length: Body, 6.8 mm. (excluding antennae and ovipositor); wings, 6.0 mm. Perkins (1939) gave the measurements as body, 8 mm.; wings, 7 mm.

TYPE LOCALITY: "Murray Island" (Baraku Island, New Georgia group).

Type in the South Australian Museum.

Perkins and May (1949) first recorded this species from Australia, bred from fruits of *Semecarpus australiensis* Engl. A large series is in the Krauss collection, bred from the same host at Cairns, Queensland, in December, 1949.

Dacus (Daculus) signatifer Tryon

Fig. 5*a–d*

Dacus signatifer Tryon 1927. Roy. Soc. Queensland, Proc. 38: 210–211.

This species very closely resembles *Dacus* (*Austrodacus*) *cucumis* French. The series of specimens at hand had been placed under *D. cucumis* until a more careful study showed that they were quite unrelated species. In body coloration they are almost exactly like *cucumis*. They differ strikingly from this by having only two developed scutellar bristles, by having cilia on the third abdominal tergum of the male, and by having a supernumerary lobe developed in the male wing. The specimens are slightly smaller in size than those of *cucumis*, the female ovipositors are very different in development (Figs. 3*c* and 5*c*), and there is a difference in the chaetotaxy of the head, in the shape of the scutellum, and in some other details. The species is readily separated from *D. murrayi* (Perkins) by the presence of the median yellow vitta, the absence of distinct black bands or vitta on the abdomen, the narrower costal band, and the differences in the female ovipositors.

This species appears to represent another borderline case which shows definite intergradations toward, or into, some of the related subgenera (genera of other authors). The specimens have rudimentary and inconspicuous secondary scutellar bristles. These are scarcely differentiated from the small setae of the scutellum and perhaps cannot correctly be called bristles. They arise in the spots where the second pair of scutellars is located in some other subgenera. They are erect, are borne on raised tubercles, and in some specimens are several times larger than the other setae (Fig. 5*a*). From the original description it would appear that this species should fit in the subgenus *Austrodacus*, but, after a thorough study of a large series of specimens, I feel that it should be placed in *Daculus*.

MALE: Entirely reddish-yellow except for the black facial spots and for a brown to black spot in the middle of the fifth tergum of the abdomen. *Head*: The facial spots are large and conspicuous; they are almost circular and extend to near the oral margin. The vertical bristles are black; the inferior fronto-orbital bristles vary from yellow-brown to blackish. The other head bristles and hairs are pale in color. The gular bristles are not differentiated from the other hairs of the gular area. Two pairs of inferior fronto-orbital bristles are present. The superior fronto-orbitals are rather poorly developed. The front is about one and one-half times longer than wide and is not spotted or noticeably discolored. The antennae are entirely pale colored and are comparatively

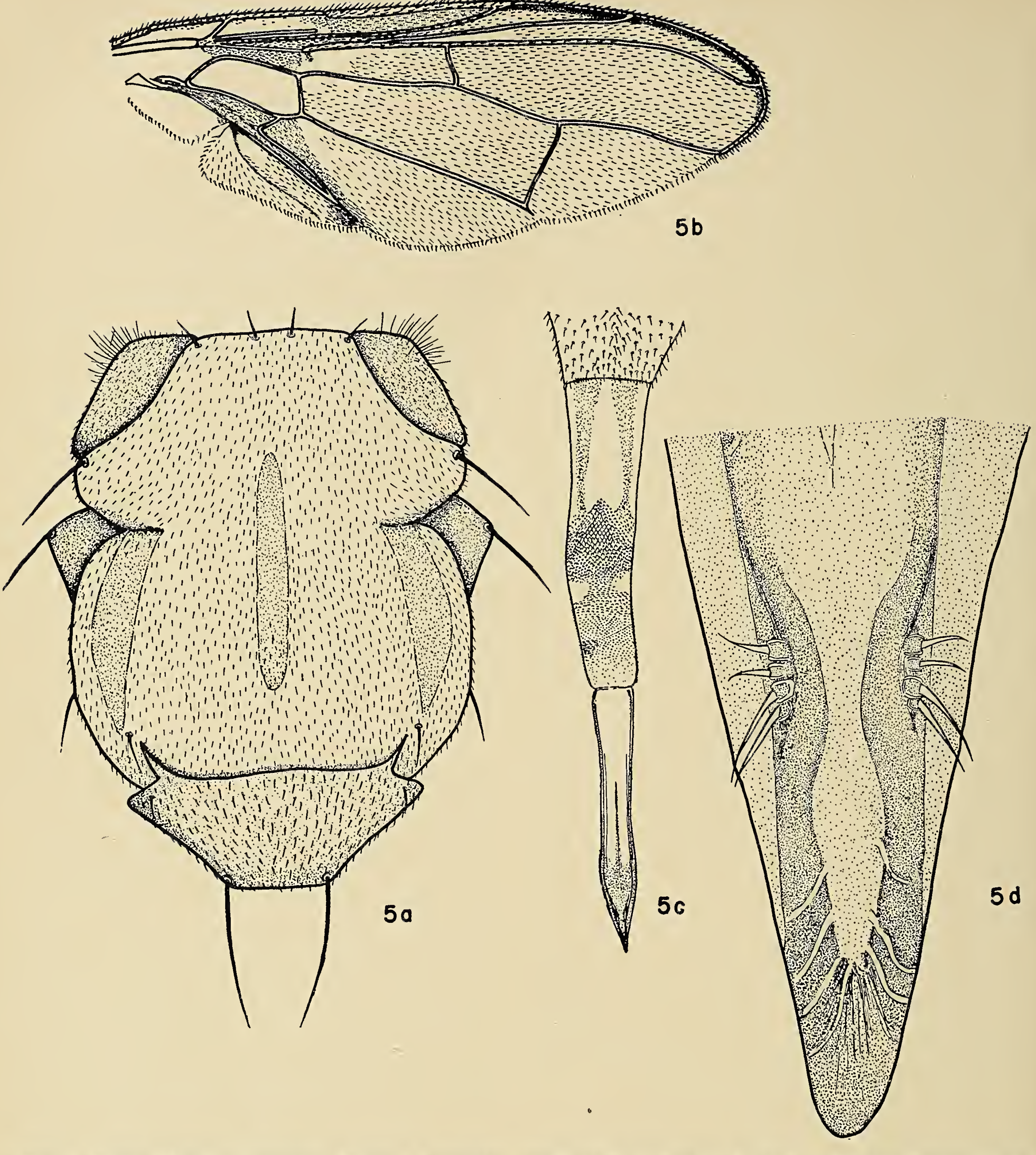

FIG. 5. *Dacus* (*Daculus*) *signatifer* Tryon: a, thorax, dorsal view; b, wing of male; c, female ovipositor, full length; d, apex of ovipositor.

short. The third segment is slightly shorter than the face and is scarcely over three times longer than wide. *Thorax*: Entirely pale colored; the three mesonotal vittae, the humeri, scutellum, notopleura, metapleura, and portions of the sternopleura and mesopleura are differentiated from the remainder of the integument by being lighter in color (cream instead of reddish-yellow). The median vitta on the mesonotum extends from a point about opposite the outer post-alar bristles to a point opposite the hind margin of the humeri. The median vitta is broad in the basal portion and somewhat narrowed anteriorly (Fig. 5*a*). The inner post-alar bristles are poorly developed compared to the outer pair; they are scarcely one-half as large. The halteres are pale yellow. The scutellum is strongly tapered, narrow, and truncate at its apex. *Legs*: Entirely yellow; the spurs of the middle tibiae are comparatively short, their length about equal to the width of the tibia. *Wings*: Chiefly hyaline, with a distinct costal and cubital band. The first two sections of the costa are faintly yellow-fumose and are devoid of microtrichia except for the apical part of the second section. The costal band is brownish, narrow, and confined to a thin strip which does not extend into cell R_3 except at the apex. The costal band extends, at least faintly, almost to the tip of vein M_1+_2 (Fig. 5*b*). The yellowish cubital streak is broad at its base, filling all of the base of cell M_4 nearly to the top edge of the m–cu crossvein. The yellow streak fades out at about the apex of the cubital cell and joins the gray spot caused by the longer, more closely spaced microtrichia along vein Cu_1+ 1st A and in the apical portion of cell 1st A. The apex of vein M_3+_4 possesses a gray, faintly yellowish spot formed by the closely set hairs. The cubital cell is strongly narrowed and is elongated. The narrowed portion of this cell is over three times longer than the distance from the apex of this cell to the wing margin. *Abdomen*: Pale yellow, except for the oblong brown to black spot in the middle of the fifth tergum and for the whitish hind border of segment 2. The pile is pale except for the long black hairs on the sides of the third tergum.

Length: Body, 4.7–5.0 mm.; wings, 4.4–4.7 mm.

FEMALE. The cubital streak is not developed beyond the apex of the cubital cell. This cell is much shorter and not as narrow as in the male. The narrowed portion of the cell is one and one-half times longer than the distance from the apex of the cell to the wing margin. *Ovipositor*: Yellow and short, scarcely extruded farther than the length of the fifth tergum. The basal section of the ovipositor is about equal in length to the fifth tergum. The ovipositor is comparatively short and broad (Fig. 5*c*); the entire length (when mounted) is about 3.7 mm. The piercer is approximately 1.1 mm. long by about 0.17 wide. It is broadly tapered toward the apex, and the setae are quite distantly spaced from the apex (Fig. 5*d*). The setae are about 0.1 mm. from the apex. This distance is comparable to four times the length of the longest (distad) pair of setae. The apex of the oviduct is about 0.22 mm. from the tip of the ovipositor. The inversion membrane (segment 8) is 1.3 mm. long by 0.33 mm. wide at its broadest point. The rasper extends to within 0.4 mm. of the base of the segment. The basal segment of the ovipositor is about 1.35 mm. long by 1.0 mm. wide, and the spiracles are about 0.45 mm. from the base of the segment measured on the lateral margins.

Length: Body, 4.8–6.0 mm.; wings, 4.5–5.7 mm.

TYPE LOCALITY: Bowen, Queensland, ex *Capparis laurifolia.*

Type No. 3135 in the Queensland Museum.

A large series of specimens has been studied from Ellis Beach near Cairns, Queensland, Jan., 1950, ex *Capparis lucida*; and from Mowbray River, Queensland, ex *Capparis lucida*, Feb., 1950.

DACUS (GYMNODACUS) Munro

Dacus (*Gymnodacus*) Munro 1938. Roy. Soc. Lond., Proc., Ser. B., Tax. 7(5): 117.

This subgenus is identical with *Dacus* (*Asiadacus*) except that the males have no supernumerary lobe in the wings. It has previously been known only from one African species, the genotype. As a result of the studies reported here, it is quite apparent that two of the Pacific species, *D. absonus* (Hering) and *D. calophylli* (Perkins and May), which were ascribed to the subgenus *Asiadacus*, actually belong in the subgenus *Gymnodacus*. These two are definitely borderline cases linking the two groups, but the lack of development of the supernumerary lobe in the wings of the male places them more closely into *Gymno-*

dacus. Asiadacus absonus Hering (1941) shows but a slight indication of a supernumerary lobe, and no distinct lobe is developed in *Asiadacus calophylli* Perkins and May. The males of these two species also lack the long shaggy pile along vein Cu_1+1st A and the spot of very densely placed microtrichia in the upper apical portion of the anal cell which is characteristic of species in those groups which have a well-developed supernumerary lobe.

GENOTYPE: *Dacus mesomelas* Bezzi (syn. *aethiopicus* Munro).

KEY TO KNOWN PACIFIC AND ORIENTAL SPECIES OF *Gymnodacus*

Crossveins r–m and m distinctly infuscated; costal band not continuous, interrupted in cell R_2 (Burma) .... *absonus* (Hering)

Crossveins not infuscated; costal band rather broad, not interrupted (Australia).... *calophylli* (Perkins and May)

Dacus (Gymnodacus) calophylli (Perkins and May)

Fig. *6a, b*

Asiadacus calophylli Perkins and May 1949. Univ. of Queensland, Dept. Biol. 2(14): 16–18.

This is the only known Australian species of *Gymnodacus*. It is easily separated by the characters given in the above key. The following are the more important characteristics.

MALE. *Head*: The front is about two times longer than wide and is not distinctly spotted on the sides. Two pairs of inferior fronto-orbital bristles are present. The third antennal segment is brownish and is comparatively short. It is just slightly longer than the face and only three times longer than wide. The facial spots are comparatively inconspicuous, small, and elongate in shape. The spots are brownish-black and are about three times longer than wide. *Thorax*: Mesonotum largely black, with the usual yellow markings; a spot just inside each humerus is reddish. The scutellum is yellow except for a very narrow black line across its base. The yellow vertical stripe on the mesopleura expands broadly on the dorsal half of the sclerite and extends anteriorly to a point opposite the anterior notopleural bristle. *Legs*: Yellow to rufous except for the brownish hind tibiae. *Wings*: The first two costal cells are hyaline to faintly yellowish-fumose and are nearly devoid of microtrichia except in the apical half of the second cell. The costal band is rather broad and fills nearly all of cell R_3. The cubital streak is not well developed, does not extend past the apex of the cubital cell, and is confined inside the cubital cell except for a small portion in the base of cell M_4. The narrowed portion of the cubital cell is very short, being only about three-fourths as long as the distance from the apex of the cell to the wing margin. There are no long shaggy hairs along vein Cu_1+1st A as are present in males which have a well-developed supernumerary lobe, and no distinct lobe is present at the apex of vein Cu_1+1st A; just a slight undulation is present in the wing margin. *Abdomen*: Perkins and May (1949) said the abdomen is "almost entirely dark brown to black except for median portion of fourth and fifth tergites which may be fulvo-ferrugineus." In the large series of specimens at hand the abdomen is predominantly rufous. The third tergum has a broad black basal band; a median black vitta extends through the third to fifth terga. A subbasal black band is present on the second tergum, and the first is brown to black on its basal half.

Length: Body, 5.0–5.5 mm.; wings, 4.5–5.0 mm.

FEMALE. In Perkins and May's figure (1949: 18) the narrowed portion of the cubital cell is shown as being longer than the distance to the wing margin beyond the apex. In the specimens at hand this latter distance is one and one-third greater than the length of the narrowed portion of the cubital cell. *Ovipositor*: In *in situ* specimens it is short and inconspicuous; the visible portion is not as long as the fifth tergum. The extended ovi-

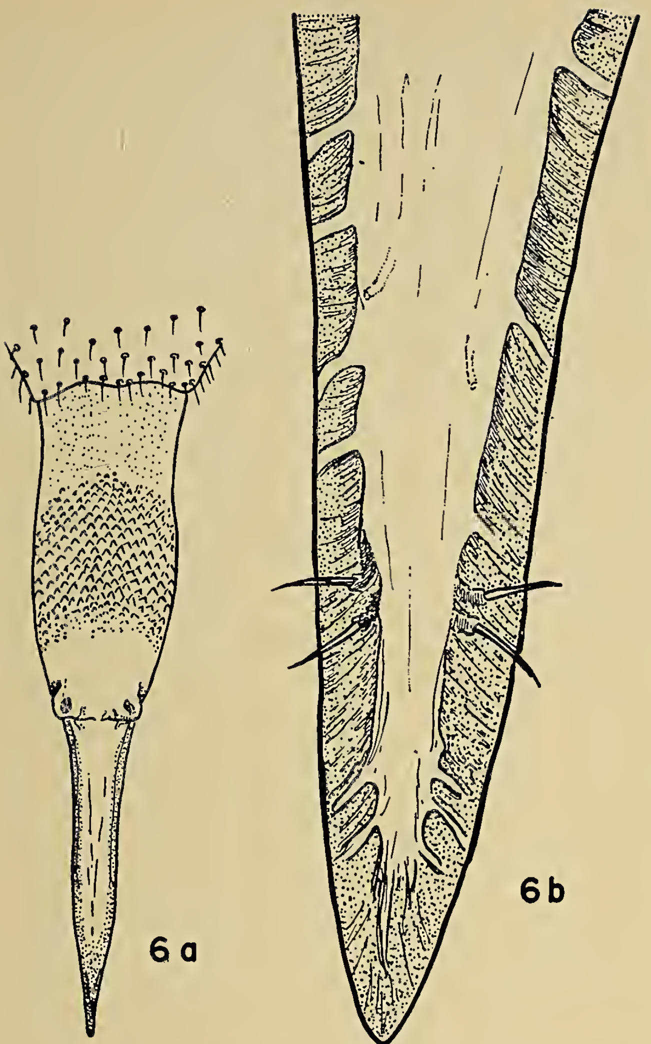

FIG. 6. *Dacus* (*Gymnodacus*) *calophylli* (Perkins and May): a, female ovipositor, full length; b, apex of ovipositor.

positor (Fig. *6a*) is just slightly over 3 mm. in length. The piercer is about 1.0 mm. long by 0.13 mm. at its widest point. It is constricted at its base (Fig. *6a*) and gradually tapered beyond the middle. The oviduct ends at about the apical two-thirds of the piercer, a distance of approximately 0.34 mm. from the apex. The setae are inconspicuous (Fig. *6b*) and are situated 0.05 mm. from the apex of the piercer. The inversion membrane is just slightly over 1 mm. in length by 0.3 mm. in width. The scales of the rasper are sharp pointed and extend to within 0.22 mm. from the base of segment 8. The basal segment is about 1.1 mm. long, and the spiracles are approximately 0.3 mm. from the base of the segment.

TYPE LOCALITY: Cairns, Queensland, ex *Calophyllum inophyllum* Linn.

Type at the University of Queensland.

Several hundred specimens were received from Krauss, collected at Cairns, ex *Calophyllum inophyllum*, June–Sept., 1949.

DACUS (HEMIZEUGODACUS) n. subgen.

The species at hand represents a borderline group which shows definite linkage with other subgenera (genera of authors). Following the concepts of other writers this group would constitute a distinct genus. Variations in the specimens of *D.* (*Hemizeugodacus*) *algaiae* n. sp. in the Krauss collection illustrate clearly, as do many other similar cases which have come to light during studies of large numbers of Dacinae, that various chaetotaxic characters which have been given generic importance are of not more than subgeneric value.

Dacus (*Hemizeugodacus*) is related to the subgenus *Parazeugodacus* Shiraki because of the presence of four scutellar and two prescutellar bristles, the presence of cilia on the third abdominal tergum of the male, and the lack of a distinct supernumerary lobe in the wings of the male. It differs from *Parazeugodacus* and related subgenera by lacking the anterior supra-alar bristles. In one specimen at hand a tiny rudimentary anterior supra-alar bristle is present on the left side, showing definite intergradation toward *Parazeugodacus.* In all other specimens studied, both anterior supra-alar bristles are completely lacking. In many respects *Hemizeugodacus* is similar to *Afrodacus,* but differs by having the four well-developed scutellar bristles and by lacking the supernumerary lobe in the wings of the males. It is also very similar to *Austrodacus* but differs by having prescutellar bristles and by having cilia on the third abdominal tergum of the male. *Hemizeugodacus* differs from *Zeugodacus* by lacking the anterior supra-alar bristles and by the poorly developed supernumerary lobe in the male wing; however, the shaggy hairs and closely set microtrichia are present.

GENOTYPE: *Dacus* (*Hemizeugodacus*) *algaiae* n. sp.

Dacus (Hemizeugodacus) algaiae n. sp.

Fig. 7*a–c*

This species very closely resembles *Dacus* (*Austrodacus*) *cucumis* (French). It is best separated by the subgeneric characters just mentioned and by the very faint costal band, the median longitudinal vitta down the abdomen, the more elongate antennae, and by the differences in the female ovipositor. Superficially the species is very similar to *D.* (*Zeugodacus*) *atrisetosus* (Perkins), but the latter has well-developed anterior supra-alar bristles.

MALE. Entirely pale reddish to yellow except for the black facial spots and the brown to black vitta down the abdomen. *Head:* Front comparatively narrow, just two times longer than wide. The front is entirely rufous except for a faint brownish discoloration in the median portion. There are two pairs of inferior fronto-orbital bristles, the lower pair spaced about their length from the oral margin. All of the head bristles are pale reddish-yellow except for the brownish tinged fronto-orbitals. The antennal grooves have a conspicuous row of short yellow hairs extending their entire length. The facial spots are suboval, longer than wide, and conspicuous. The third antennal segment is brownish tinged, slender, and elongate (for a *Dacus*); it is one and one-third longer than the face and its greatest width is equal to slightly less than one-fourth its length. *Thorax*: With three postsutural yellow vittae which extend from the suture to a line running between the lower pair of post-alar bristles. The median vitta is broad, is somewhat narrowed in the anterior part, and broadened behind. At its widest point it is almost equal to the distance between the prescutellar bristles. The lateral vittae are narrow, about half as wide as the median. The scutellum, humeri, notopleura, and the usual pale areas of the pleura are clear yellow. The halteres are yellow. The bristles of the thorax are yellow-red in color. *Legs*: Entirely yellow to rufous. The apical spurs of the middle tibiae are reddish, the length of the spurs is equal to about two times the greatest width of the tibiae. *Wings*: Faintly fumose as seen in reflected light, often with broad, faintly yellowish bands along all of the veins and crossveins. The costal band is faintly brownish and inconspicuous beyond the fourth costal section. The band is narrow and does not extend below vein R_3 except at its apex. The first two sections of the costa are yellowish-fumose. The first section is devoid of microtrichia except along the top margin. The second section is chiefly filled with microtrichia. The cubital streak is pale brown, fills all of the basal portion of cell M_4 to the base of the m–cu crossvein, but fades out before it reaches the wing margin (Fig. 7*a*). The narrowed portion of the cubital cell is slightly less than two times longer than the distance from the apex of cell Cu to the wing margin. A slight undulation is present in the wing margin at the apex of vein Cu_1+1st A, but no distinct lobe is present. *Abdomen*: With no dark-colored crossbands and with the longitudinal median vitta extending almost the full length of the abdomen fading out on the second tergum. The lateral hairs of the third tergum are reddish.

Length: Body, 6.2 mm.; wings, 5.9 mm.

FEMALE. The brownish-yellow cubital streak ends about halfway between the apex of cell Cu and the wing margin. The narrowed portion of cell Cu is about equal in length to the distance from its apex to the wing margin. The abdomen is similar to that of the male but lacks the cilia on the third tergum. The ovipositor is reddish-yellow, often tinged with brown. *Ovipositor*: The ovipositor is not conspicuous in undissected specimens; the visible portion is about equal in length to the fifth abdominal segment. The entire ovipositor, about 4.6 mm. in length, is comparatively short (Fig. 7*b*). The piercer (Fig. 7*c*) is 1.5 mm. long by about 0.3 mm. wide and is gradually tapered beyond the apex of the oviduct. The tip of the oviduct is about 0.23 mm. from the apex of the ovipositor. There

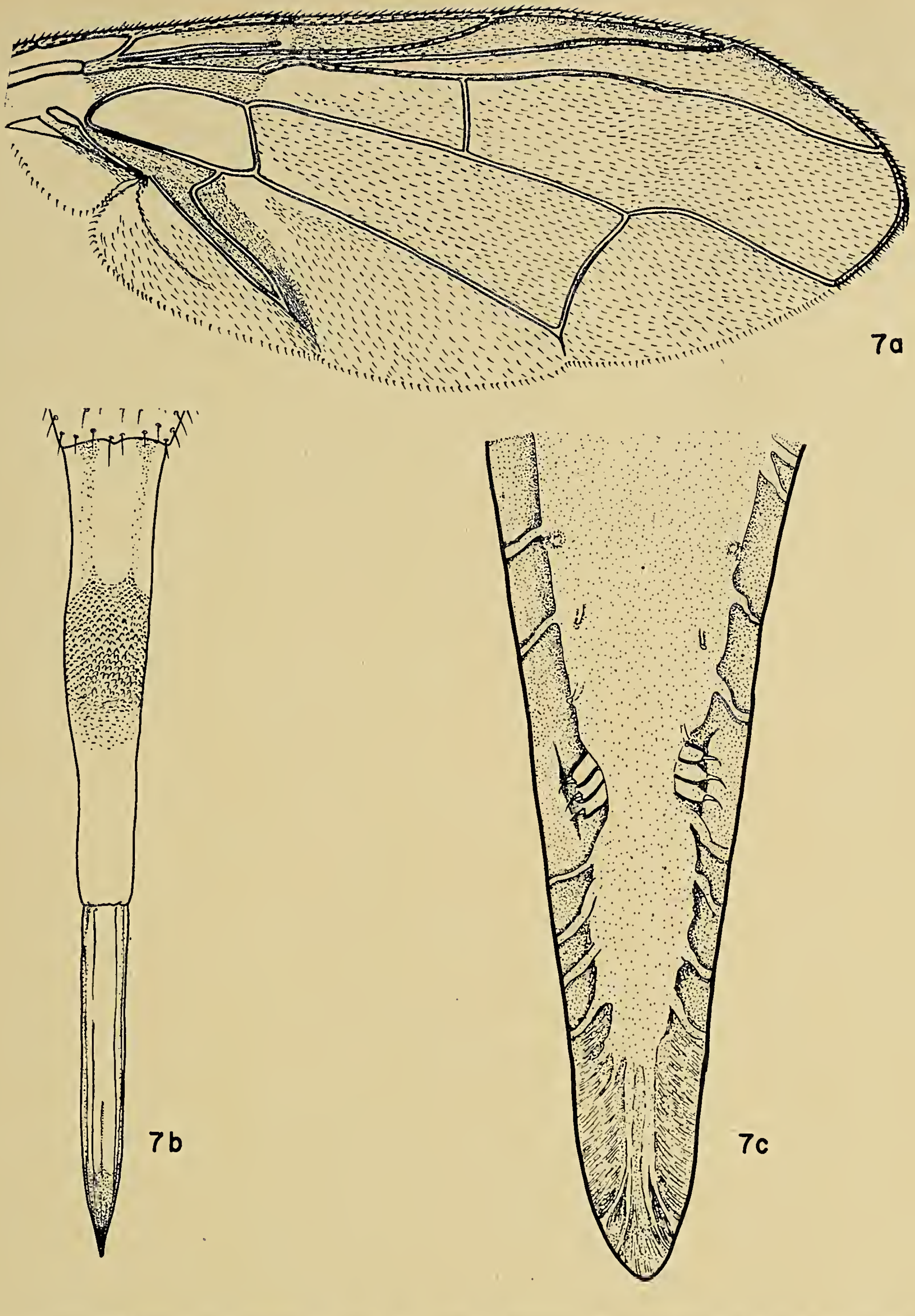

FIG. 7. *Dacus* (*Hemizeugodacus*) *algaiae* n. sp.: a, wing of male; b, female ovipositor, full length; c, apex of ovipositor.

are no apparent preapical setae as in other Dacinae. Under high-power magnification it appears that there are three pairs of very tiny setae located about 0.09 mm. from the apex of the ovipositor. In the specimens studied these could not be clearly defined even under oil immersion. The inversion membrane (segment 8) is about 1.7 mm. long by 0.3 to 0.4 mm. wide at the broadest point. The rasper extends to within about 0.58 mm. from the base of the segment. The scales of the rasper are blunt, mostly rounded at their apices, and not drawn out into points. The basal segment of the ovipositor is about 1.4 mm. long by about 1.0 mm. wide at its broadest point. The spiracles are about 0.5 mm. from the base of the segment.

Length: Body, 6.2–7.0 mm.; wings, 5.9–6.6 mm.

Holotype male, allotype female, and 18

paratypes (10 males and 8 females): Atherton Tableland, Queensland, Nov., 1949, ex *Aglaia ferruginea.* Also, two paratype females: near Atherton, Queensland, Feb., 1950, ex *Aglaia sapindina.*

Holotype, allotype, and four paratypes have been deposited in the United States National Museum. The remainder of the paratypes are being distributed to the following museums and individual collections: Australian Museum, Sydney, Australia; Bishop Museum, Honolulu, T. H.; Board of Agriculture and Forestry, Honolulu, T. H.; Hawaiian Sugar Planters' Association, Honolulu, T. H.; University of Hawaii, Honolulu, T. H.; the collection of Dr. H. K. Munro, Pretoria, South Africa; and the collection of Dr. M. Hering, University of Berlin.

DACUS (HETERODACULUS) n. subgen.

This subgenus is very closely related to *Dacus* (*Daculus*) but is differentiated by the lack of the supernumerary lobes in the wings of the males. If the generic concepts used by various other workers in this group were followed, this difference would justify setting up a new genus for the species at hand. I am not in favor of this procedure and prefer that genera not be based upon secondary sexual characters unless accompanied by ample supporting characters, preferably characters common to both sexes. The wing venation is considerably different from that of known species of the subgenus *Daculus*, and, on the basis of a comparison of *Dacus* (*Heterodaculus*) *visendus* n. sp. with the described species of the subgenus *Daculus*, it would appear that they should be placed in different genera. However, on the basis of a broad comparative study of the characters throughout the subfamily Dacinae, these characters do not appear to be of more than subgeneric importance. The variations and intergradations of the intrageneric characters of the genus *Dacus* sens. lat. encompass the structural differences seen in the species at hand.

Aside from the secondary sexual characters mentioned above, the subgenus differs from *Daculus* and other closely related subgenera by having the r–m crossvein situated below the middle of the discal cell. The section of cell R from the fumose portion (directly above the base of vein M_{3+4}) to the r–m crossvein is very short compared to the same section in *Daculus* and most other *Dacus*. This portion of cell R is slightly shorter than cell M (Fig. 8*c*). In all the known species of *Daculus* and almost all known species of *Dacus* the r–m crossvein is situated beyond the middle of the discal cell, and the apical portion of cell R (beyond the fumosity) is about one and one-half times longer than cell M (Fig. 5*b*). In *Heterodaculus* the apex of vein R_{1+2} is well beyond a point opposite the r–m crossvein; the top of the crossvein is almost opposite the middle of the third section of the costa. In *Daculus* and other *Dacus*, with a few exceptions, the top of the r–m crossvein is about opposite the apex of vein R_{1+2} and the bottom is slightly beyond its apex. At least three species of *Dacus* (*Strumeta*)—*recurrens* (Hering), *pulcher* (Tryon), and *manskii* (Perkins and May)—have the r–m crossvein located in this more anterior position, so this would probably not be a valid generic character. The apical portion of vein M_{3+4} is more elongate and the lower corner of cell 1st M_2 is farther from the wing margin than in other *Dacus* species which I have studied. The vein reaches four-fifths of the distance to the wing margin, and the distance from the lower corner of cell 1st M_2 to the margin is equal to about one-third the length of the m crossvein. The head possesses three to four pairs of inferior fronto-orbital bristles. A pair of small but conspicuous postocellar bristles is also present.

GENOTYPE: *Dacus* (*Heterodaculus*) *visendus* n. sp.

Dacus (Heterodaculus) visendus n. sp.

Fig. *8a–e*

This species is distinguished from other Dacinae by the characteristics discussed just above. The pattern of the wing maculation will readily separate it from all other known species.

MALE. *Head:* Entirely yellow, tinged with reddish, except for the moderately large oblong black facial spots and for a dark brown spot just below the lower margin of each eye. The facial spots are about two times longer than wide and extend to near the oral margin. The vertical bristles are very well developed and are black in color. The other head bristles are brown, except for the yellow gular bristle and the yellow postoccipital row. The front is parallel sided and two times longer than wide. (Fig. 8*a*). The slightly raised median portion of the front between the inferior fronto-orbital bristles is discolored with brown to black, and the area around the bases of the superior fronto-orbital bristles is often brown. The inferior fronto-orbitals vary in number from three to four pairs; the average specimens have three pairs. The face is slightly convex on the upper portion with an indentation or indistinct transverse groove across the middle. The lower portion of the face is straight. The third antennal segment is dark brown to blackish and is distinctly longer than the face. The third segment is not, however, conspicuously elongated; it is just slightly more than four times longer than wide. *Thorax:* Predominantly yellow-red in ground color with some dark patterns on the mesonotum and the pleura. As is typical of the subgenus the scutellum has but one pair of bristles; the prescutellar and anterior supra-alar bristles are lacking. The scutellum is entirely pale yellow except for a narrow reddish-brown band at its base. The mesonotum has three postsutural yellow (or cream) vittae. The two lateral vittae are comparatively short and end one-third to nearly one-half their length from the posterior supra-alar bristles. The median vitta is two or more times wider than the laterals, it extends from the suture almost to the scutellum, and is broadest at its base and gradually narrowed anteriorly. The humeri, notopleura, and portions of the mesopleura, sternopleura, and metapleura are pale yellow. The yellow markings of the mesopleura extend broadly along the dorsal margin of the sclerite and connect with the humeri (Fig. 8*b*). The dark pattern of the mesonotum is rather irregular and appears to be somewhat variable. In general there is a dark line on each side, extending just inside the lateral yellow vittae from the outer scapular bristles to a line opposite the posterior supra-alar bristles. Just in front of the suture these marks expand laterally and extend toward the bases of the anterior notopleural bristles. The metanotum is dark brown to black on the sides and is tinged with rufous in the median portion. The halteres are yellow. *Legs:* Entirely yellow, except for the brown to blackish hind coxae and tibiae and the slightly discolored apical subsegments of the tarsi. *Wings:* Conspicuously marked by a variable pattern which extends transversely through the middle of the wing. The costal band is yellow-brown to yellow-gray. The band extends through all of cell R_3, except for a portion of this cell lying directly below the apex of vein R_{1+2}. The band is faint, but distinct, in cell R_3 and does not extend noticeably beyond the tip of vein R_{4+5}. The first two sections of the costa are yellowish-fumose and are densely covered with microtrichia except for the anterior half of the first section. The cubital streak is very broad and conspicuous; it fills the basal portion of cell M_4 but does not extend to the top margin of the m–cu crossvein. The brownish streak extends almost to the apex of vein Cu_1+1st A. The area along vein Cu_1+1st A, on the underside of the wing has the usual long matted microtrichia and the large gray spot which extends through the apex of the 1st anal cell. This area is not as conspicuously darkened or hairy as in the *Daculus* which have been studied. An irregular, yellow-brown-

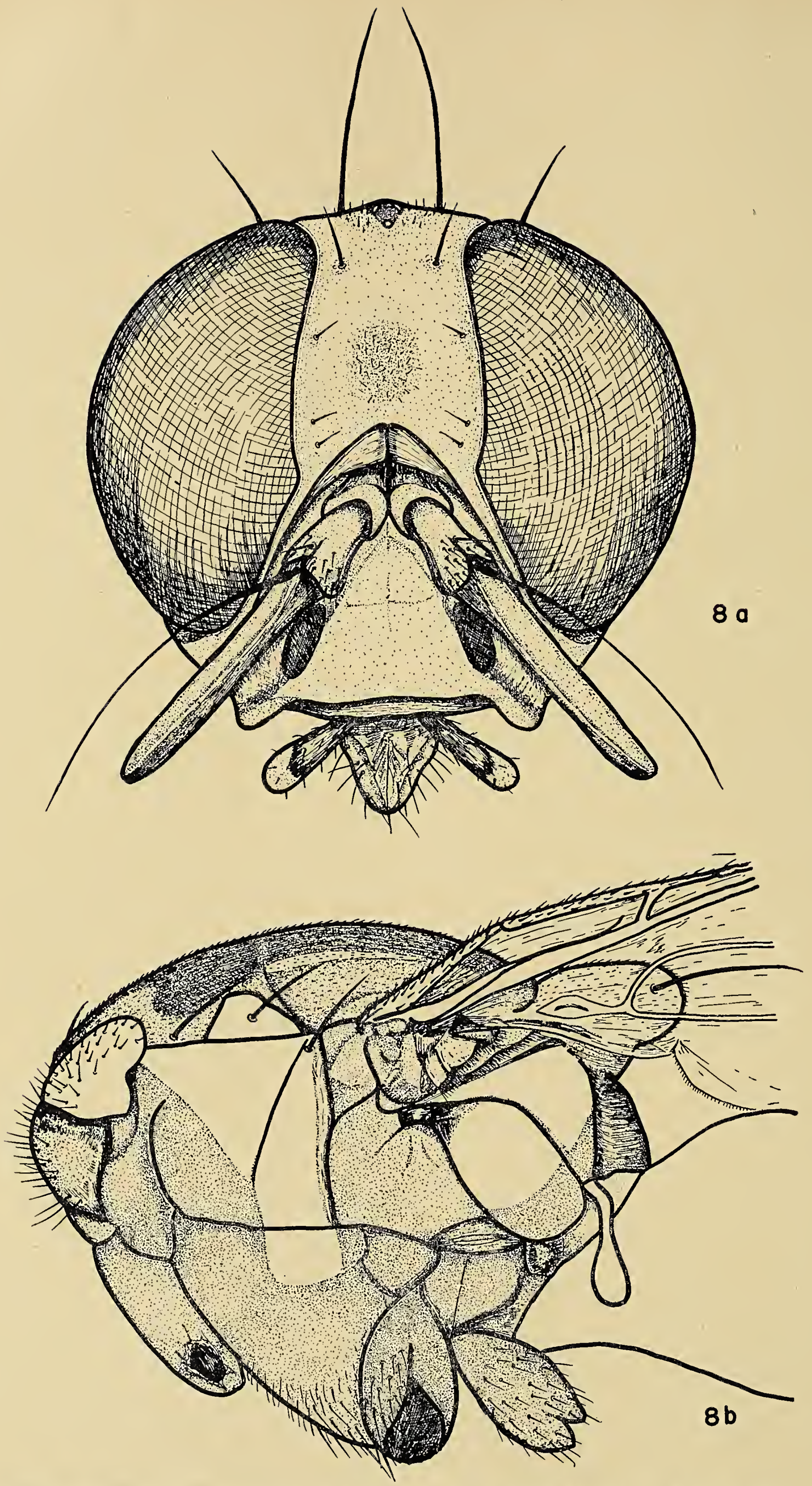

FIG. 8A. *Dacus* (*Heterodaculus*) *visendus* n. sp.: a, head; b, thorax, lateral view,

fumose streak extends through the middle part of the wing from the costal band opposite the r–m crossvein to the apex of vein M_{3+4}. This band extends broadly over the r–m crossvein, along vein M_{1+2} from just before the r–m to the m crossvein, and along

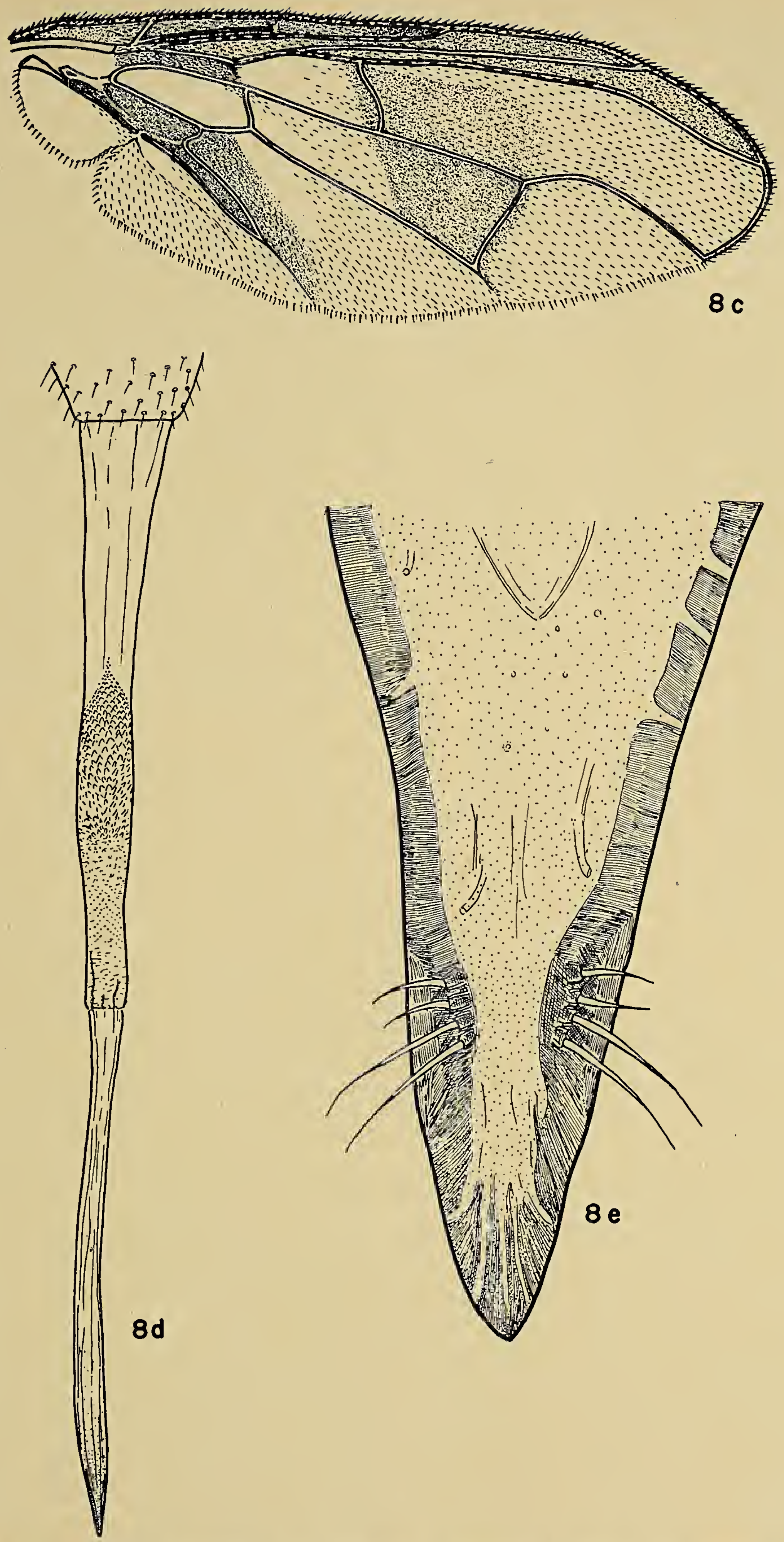

FIG. 8B. *Dacus* (*Heterodaculus*) *visendus* n. sp.: c, wing of female; d, female ovipositor full length; e, apex of piercer.

the inside margin of the m crossvein. Usually the apical third of the discal cell (1st M_2) is almost completely fumose (Fig. 8*c*); in some specimens the fumosity extends just along the crossveins and along the middle part of vein M_{1+2} in a Z-shaped pattern. The portion of cell R directly above cell M is very densely covered with microtrichia. In the outer portion of this area, just above vein M, the microtrichia appear to be longer and more dense. The cell is dark brown to black in this portion. The wing shows a very slight undulation at the apex of the vein $Cu_1+1st\ A$, but there is no developed lobe at this point. Vein $Cu_1+1st\ A$ fades out before the wing margin. The distance from the apex of the cubital cell to the wing margin is slightly more than half the length of the narrowed portion of cell Cu. *Abdomen:* Chiefly yellow to rufous in the median portion of the dorsum and brown to blackish on the sides. The first tergum is almost entirely dark colored, with just a narrow yellow apical margin. The second tergum has a broad dark-colored band across its base and the apical half is yellow to whitish. The third and fourth terga have a broad yellowish band extending longitudinally down the middle. This extends over the fifth tergum and expands laterally to cover all of that sclerite except for narrow black lateral margins. The third tergum has a row of long black hairs on each side.

Length: Body, 6.5 mm.; wings, 5.7 mm.

FEMALE. Very similar to the male except for the sexual characters. The cubital streak is equally well developed but the longer, more closely arranged microtrichia are not present along vein $Cu_1+1st\ A$ or in the 1st A cell. The narrowed portion of cell Cu is shorter than in the male. This portion is about one and one-third longer than the distance from the apex of cell Cu to the wing margin. *Ovipositor:* Yellow-red and rather conspicuous. In the majority of specimens the extruded ovipositor (*in situ*) is equal in length to the last three abdominal segments (3–5). The basal portion (segment 7) is one and one-third longer than segment 5. The ovipositor is rather long and slender when relaxed and when extended (Fig. 8*d*) it measures approximately 6.4 mm. The piercer measures about 2.1 mm. long by 0.18 mm. at its widest point. The apex of the oviduct is comparatively near the tip of the ovipositor (0.15 mm.) and the piercer is gradually tapered beyond this point (Fig. 8*e*). The four pairs of subapical setae are about 0.05 mm. from the apex of the piercer, about two times the length of the longest (distad) setae. The inversion membrane (segment 8) is about 2.4 mm. long by 0.3 mm. wide at its broadest point. The rasper extends to about 1.0 mm. from the base of the segment. The basal segment (seventh) is approximately 1.9 mm. long by 1.4 mm. wide, measured across the anterior margin. The spiracles are located about 0.5 mm. from the base of segment 7, measured on the lateral margins.

Holotype male, allotype female, and 100 paratypes (55 males and 45 females): Babinda, Queensland, Australia, Jan., 1950, ex *Garcinia kajewskii.*

Holotype, allotype, and eight paratypes deposited in the United States National Museum. The remainder of the paratypes are being distributed among the following museums and collections: Bishop Museum, Honolulu, T. H.; Australian Museum, Sydney; Board of Agriculture and Forestry, Honolulu, T. H.; Hawaiian Sugar Planters' Association, Honolulu, T. H.; and the University of Hawaii, Honolulu, T. H.

DACUS (MELANODACUS) Perkins

Melanodacus Perkins 1937. Roy. Soc. Queensland, Proc. 48(9): 57.

This subgenus is in the *Zeugodacus* complex because of the presence of four scutellar bristles. It differs from *Zeugodacus* by having no cilia on the third tergum of the male. It is closely related to *Paratridacus* Shiraki and is separated by the presence of a supernumerary lobe in the male wing.

Only a single species is known from Australia.

GENOTYPE: *Dacus niger* Tryon.

KEY TO KNOWN SPECIES OF *Dacus* (*Melanodacus*)

Face yellow, with the usual black spots
(Australia) . . . . *niger* Tryon
Face entirely black (New Guinea) . . . .
. . . . *satanellus* (Hering)

Dacus (Melanodacus) niger Tryon

Fig. 9*a*, *b*

Dacus niger Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 211–212.

This species was not collected by Krauss but a specimen from the Sydney area was sent in by him. It is easily separated from all known Australian Dacinae by its very black coloration, by the absence of yellow vittae on the mesonotum, as well as by the subgeneric characters.

MALE. *Head:* Occiput black except for a narrow yellow margin. The front is over two times longer than wide and with brownish spots on the sides and a brownish discoloration in the median portion. The facial spots are suboval, drawn into a point on the underside. The third segments of the antennae are about one and one-third times longer than the face and nearly four times longer than wide. *Thorax:* Entirely shining black except for the hind three-fourths of the humeri, the notopleural calli, the sides of the scutellum, the metapleura, and the posterior two-thirds of the mesopleura which are yellow; the halteres are also yellow. The mesonotum is very minutely punctulate. *Legs:* Coxae and trochanters brown to black, femora yellow except for brown to black apices of the hind pair. Tibiae yellowish-red tinged with brown; the hind pair is darker in color, sometimes chiefly blackish. The tarsi are yellow, the apical subsegments are brownish tinged. *Wings:* Entirely hyaline except for a brownish stigmal spot and a faint indication of a costal band along the margin in the apex of cell R_3. The cubital streak is not present although the base of the cubital cell is slightly yellowed. The narrowed portion of the cubital cell is very short; it is about half as long as vein Cu_1+1st A. *Abdomen:* Strongly narrowed basally, rather oval in shape. Entirely black except for two elongate yellow spots on the hind margin of the second tergum separated by a median black portion. The fifth tergum has a pair of narrow yellow marks extending longitudinally down the middle of the segment separated by a black vitta.

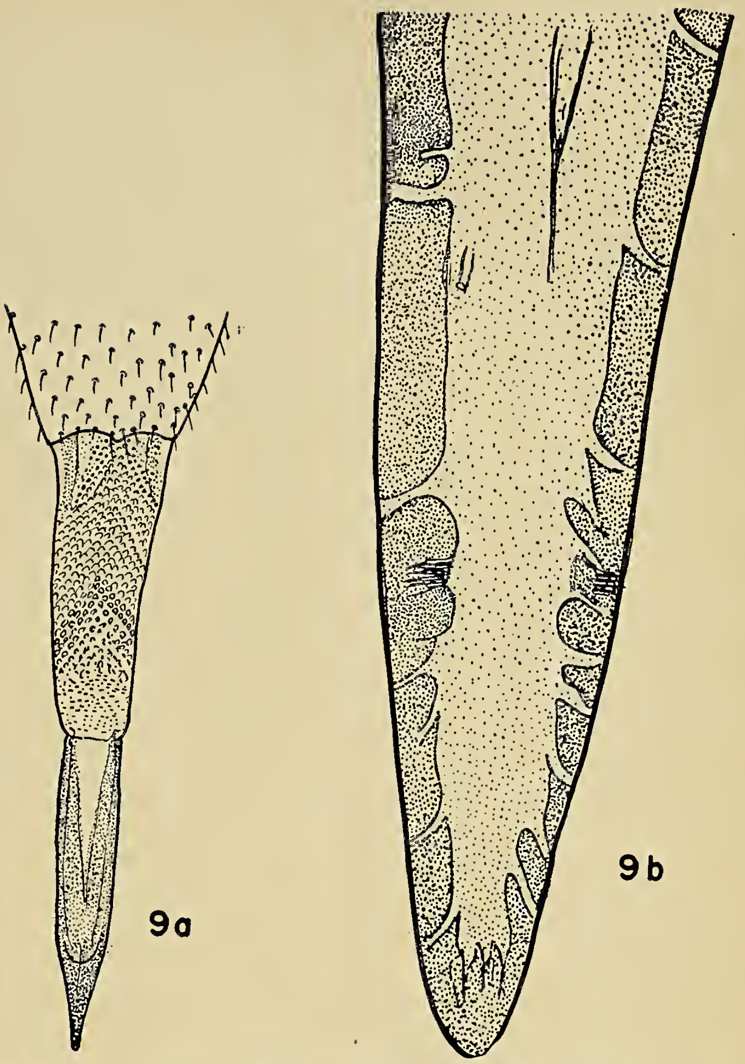

FIG. 9. *Dacus* (*Melanodacus*) *niger* Tryon: a, ovipositor, full length; b, apex of ovipositor.

Length: Body, 5.0 mm.; wings, 4.0–5.0 mm.

FEMALE. The narrowed portion of the cubital cell is more elongate than in the male; it is about three-fourths as long as vein Cu_1+1st A. *Ovipositor:* The basal segment is black, the remainder is reddish. In *in situ* specimens the visible portion of the ovipositor is about one and three-fourths times longer than the fifth tergum. The extended ovipositor is very short (Fig. 9*a*), being approximately 3.0 mm. long. The piercer and the inversion membrane are both about 1.0

mm. long. The piercer (Fig. 9*b*) is about 0.16 mm. wide and the eighth segment is 0.25 mm. wide. The oviduct opens at the apical two-thirds of the piercer, about 0.3 mm. from the apex. The setae are very tiny and inconspicuous; they are about 0.06 mm. from the tip of the piercer. The scales of the rasper are blunt and extend to the base of the eighth segment. The basal segment of the ovipositor is about 1.1 mm. long by 0.9 mm. wide; the spiracles are about 0.28 mm. from the base of the segment.

TYPE LOCALITY: Cleveland, South Queensland, ex *Symplocos thwaitesii* F.v.M.

Type in the Queensland Museum.

One female specimen was sent in by Mr. Krauss labeled "in trap, St. Ives, near Sydney, Oct. 29, 1941." (Collector not given.)

DACUS (PARATRIDACUS) Shiraki

Paratridacus Shiraki 1933. Fac. Sci. Agr., Taihoku Imp. Univ., Mem. 8(2): 109–110.

This subgenus is closely related to *Dacus* (*Zeugodacus*) and is distinguished only by secondary sexual characters. The males differ by having no cilia on the third abdominal tergum and no supernumerary lobe in the wing. The group apparently contains but one species; it is widely distributed and quite variable in coloration.

GENOTYPE: *Dacus* (*Paratridacus*) *expandens* Walker.

Dacus (Paratridacus) expandens Walker

Fig. 10*a*, *b*

Dacus expandens Walker 1859. Linn. Soc. Lond., Proc. 3: 114.

Bactrocera garciniae Bezzi 1913. Ind. Mus. Mem. 3: 97–98. New synonymy based upon a large series of specimens from a wide range of localities and upon a comparison of specimens with the type in the British Museum.

Dacus yayeyamanus Matsumura 1916. Thousand Insects of Japan, Addit. 2: 412. New synonymy based upon a comparison of specimens from Japan with specimens from numerous other areas.

This is a moderately large, chiefly pale-colored species which is distinguished from all known Dacinae by the subgeneric characters stated above. The females are also distinctive because of their peculiarly developed ovipositor (Fig. 10*b*). The coloration is apparently quite variable and does not appear to be reliable as a specific character. The specimens on hand from Australia are quite consistently pale colored. None in the series at hand has black markings on the mesonotum, and the abdomen and legs are not as distinctly marked with black as in specimens from the Philippines, Japan, and some other regions.

MALE. The front is nearly one and three-fourths times longer than broad and is slightly discolored with brown in the median part at the bases of the bristles. There are normally two pairs of inferior fronto-orbital bristles; one specimen at hand has four well-developed inferior fronto-orbitals on one side of the face and two on the other. The facial spots vary in size and shape from small and circular to rather large oval to subquadrate. The third antennal segment is brown, one and one-third times longer than the face, and nearly five times longer than wide. *Thorax:* Typically rufous, except for the two yellow post-sutural stripes, yellow humeri, and the usual yellow markings. The scutellum is normally yellow but is discolored with reddish in some specimens. The mesonotum often has brown to blackish submedian vittae extending longitudinally before and behind the suture. The pleura are usually all pale, but in some specimens the sternopleura, hypopleura, pteropleura, and the front margin of the mesopleura are extensively black. The metanotum varies from yellow to rufous in the center and from brown to black on the sides. *Legs:* Varying in coloration from all reddish to yellow, except for brownish coxae and apical subsegments of tarsi, to having a brown to black spot on the underside of the apex of each femur, and to having the tibiae tinged with brown. *Wings:* With a broad costal band and cubital streak. In teneral specimens the wing markings are very faint to absent. The first two costal cells are subhyaline to distinctly yellowish. The first cell has microtrichia only in the apical dorsal portion and the second cell is pilose except in the lower basal portion. The costal band extends through cell R_3 to vein R_{4+5}. The cubital streak fills all of the basal part of cell M_4 and extends almost to the top margin of the m–cu crossvein. The streak fades out shortly beyond the apex of the cubital cell and there are no dense, shaggy hairs or closely set microtrichia along vein Cu_1+1st A. The narrowed portion of the cubital cell is about one and one-third times longer than the portion from the apex of the cubital cell to the wing margin. *Abdomen:* Chiefly rufous with a brown to black basal band on the third tergum and a brown to black median vitta extending down terga 3 to 5. The bases of terga 1 and 2 are also brownish; the subbasal band on the second is sometimes black. The median vitta and the basal band on the third are variable. In some specimens, only the posterior lateral margins of the third tergum and the median portion of the fifth are distinctly marked with brown to black.

FEMALE. The narrowed portion of the cubital cell is just slightly longer than the distance from the apex of that cell to the wing margin. *Ovipositor:* Short and inconspicuous in dry specimens. The exposed portion of the ovipositor is shorter than the fifth tergum. In *in situ* specimens the apex of the piercer and its peculiar distinctive shape can usually be seen. The extended ovipositor (Fig. 10*a*) is about 3.0 mm. long. The piercer has a characteristic constriction at its base and its apex is distinctively shaped. The piercer is approximately 1.4 mm. long by 0.19 mm. at its widest point. The oviduct extends to within approximately 0.21 mm. from the apex of the piercer. Slightly beyond the halfway point between the end of the oviduct and the apex the piercer is strongly constricted with a lobe-like projection on each side as in Figure 10*b*. The narrowed apical portion is about 0.08 mm. long. The setae are very inconspicuous and are situated at the basal three-fourths of the narrowed portion, about 0.06 mm. from the apex of the piercer. The inversion membrane is approximately 1.4 mm. in length by 0.7 mm. wide. The scales are broad and blunt and extend to within 0.09 mm. of the base. The basal segment of the ovipositor is about 1.3 mm. long by 1.2 mm. wide and the spiracles are located 0.23 mm. from the posterior lateral margins of the segment.

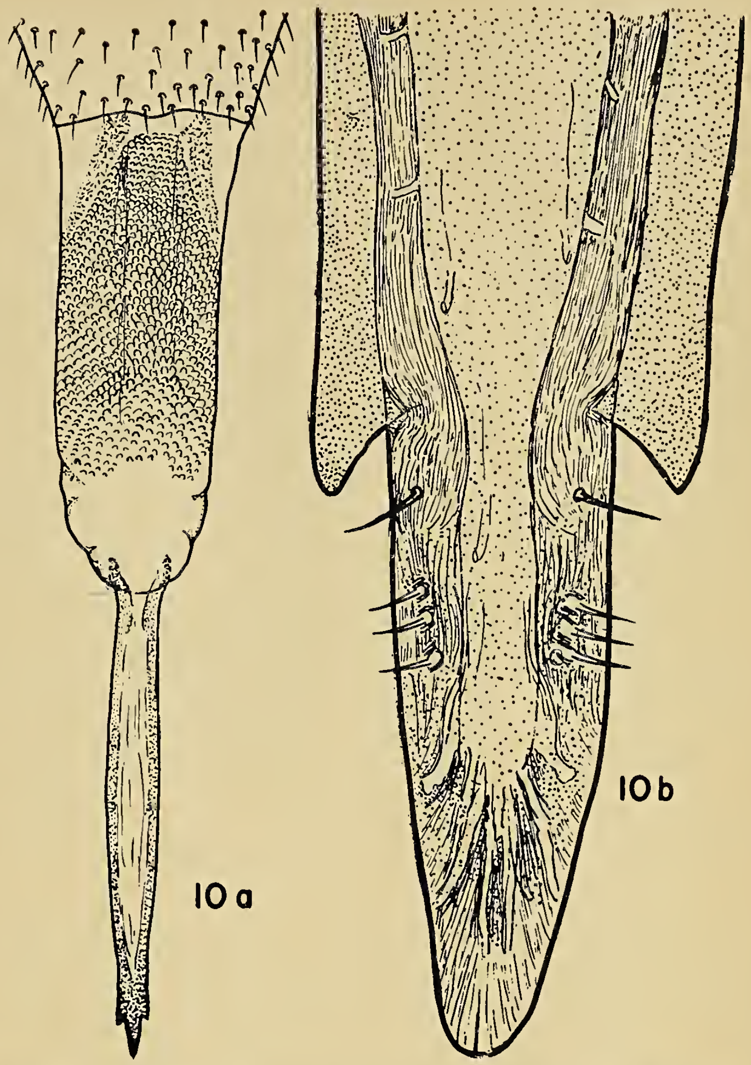

FIG. 10. *Dacus* (*Paratridacus*) *expandens* Walker: a, ovipositor, full length; b, apex of ovipositor.

Length: Body, 8.0–10.0 mm.; wings, 7.5–8.5 mm.

TYPE LOCALITY: "Aru Islands" (Aroe Island).

Type in the British Museum.

Twenty specimens are in the Krauss collection from Cairns, Queensland, ex *Garcinia xanthochymus*, Aug.–Nov., 1949.

This species is apparently widely distributed. I have studied numerous specimens from Japan, the Philippine Islands, Ceylon, and India.

DACUS (STRUMETA) Walker

Strumeta Walker 1856. Linn. Soc. Lond., Proc. 1: 33.

Dasyneura Saunders 1841. Ent. Soc. Lond., Trans. 3: 60 (nec Rondani, 1840).

Chaetodacus Bezzi 1913. Ind. Mus. Mem. 3: 93.

Dacus (*Marquesadacus*) Malloch 1932. B. P. Bishop Mus. Bul. 98: 145.

The subgenus *Strumeta* contains the greatest number of species of any of the Australian or Pacific Dacinae. There are 17 species[5] and 3 varieties now known from Australia. All of these were represented in the Krauss collection except *D. bancrofti* (Tryon) and *D. strigatus* (Perkins). The members of this subgenus are characterized by having two scutellar bristles, a pair of prescutellars, and a pair of anterior supra-alars; by having the supernumerary lobe developed in the male wing; and by having a row of cilia on each side of the third tergum of the male.

GENOTYPE: *Dacus umbrosus* Fabricius.

KEY TO KNOWN SPECIES OF *Dacus* (*Strumeta*) FROM AUSTRALIA

1. Wings with one or more transverse markings; at least the r–m cross-vein infuscated.................. 19

Wings marked only with the costal band and the cubital streak....... 2

2. Scutellum yellow except for a narrow basal margin................... 4

Scutellum with a large brown spot covering most of the disc or the apex......................... 3

3. The brown spot on the scutellum extends from the base over most of the disc, margin pale; fifth abdominal segment with a large brown to black spot on each side; mesonotum brownish with no black markings..............*halfordiae* (Tryon)

The brown spot covers just the apex of the scutellum; abdomen entirely orange, no brown to black markings; mesonotum extensively marked with black...*bancrofti* (Tryon)

4. Costal band broad, extending to or slightly below vein R_{4+5}, filling all of cell R_3; female ovipositor as in Figures 13*a* and 13*b*...*bryoniae* (Tryon)

Costal band narrower, extending scarcely, if at all, below vein R_3 except at the wing margin; ovipositor not as above.................. 5

5. The first two costal cells are covered with microtrichia except in the basal half of the first cell; these cells are yellow-brown-fumose, concolorous with the costal band.............................(*tryoni* complex) 6

First two costal cells devoid of microtrichia except in the apex of the second section and rarely a narrow row along top margin of the first; these cells are usually hyaline, distinctly paler than the costal band . 9

6. Humeri concolorous with the notopleural calli and the postsutural yellow stripes.................. 7

Humeri discolored, faintly to distinctly brownish; not concolorous with the yellow markings of the mesonotum . *tryoni* var. *neohumeralis* n. name

7. Mesonotum without black markings, except sometimes a pair of small black marks near the anterior margin...........*tryoni tryoni* (Froggatt)

Mesonotum with black vittae, or extensively marked with black...... 8

8. Predominantly brown to black, melanistic forms, thorax and abdomen

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[5] "*Bactrocera longicornis* Guer." cannot be recognized from the original description and is not included in this list. Some writers have considered it a synonym of *D. umbrosus* Fab.

chiefly dark colored . . . .*tryoni* var. *melas* (Perkins and May)

Not so dark colored, intermediate forms, mesonotum with rufous areas separating the black vittae. . . . . *tryoni* var. *sarcocephali* (Tryon)

9. Thorax and abdomen entirely pale, with no dark markings; female ovipositor very elongate, the exposed portion longer than the combined lengths of abdominal segments 3 to 5; facial spots produced into a sharp point below. . . . . *fagraeus* (Tryon)

Thorax and (or) abdomen with brown to black markings; ovipositor comparatively short, not as long as segments 3 to 5; facial spots usually oval, not sharp-pointed below. . . . 10

10. Dorsum of thorax pale, without brown to black markings 17

Dorsum distinctly marked with dark brown to black. 11

11. Dorsum of thorax almost entirely black. 12

Mesonotum marked with longitudinal dark brown to black lines separated by rufous areas; or with a narrow median black vitta 13

12. Abdomen all rufous except for a narrow black band at the base of the third tergum; female ovipositor rather elongate, the visible portion equal to the combined lengths of segments 4 and 5. . . . . . *musae* (Tryon)

Abdomen with a broad median vitta extending over terga 3 to 5; sides of terga 3 and 4 blackish; ovipositor short, visible portion about equal to segment 5. . . . . *endiandrae* (Perkins and May)

13. Mesonotum rufous except for a narrow median vitta and a black spot in front of scutellum . . . . *cacuminatus* (Hering)

Mesonotum without a median vitta. . 14

14. Female ovipositor very short, *in situ* the visible portion is not over one-half as long as the fifth tergum; the costal band is very narrow, not extending beneath cell R_3 except at its apex; vertical stripe on mesopleura broadened on the dorsal portion, extending anteriorly to a point opposite the anterior notopleural bristle. . . . . *breviaculeus* n. sp.

Visible portion of ovipositor at least longer than segment 5; costal band extending distinctly below R_3; mesopleural stripe narrower, extending anteriorly to a point about opposite the front edge of the notopleural callus. 15

15. Abdominal terga 3 to 5 with a median black vitta down the middle; ovipositor short (Fig. 20*a*), the extended ovipositor measuring only about 3.5 mm. . . . . *mayi* n. name

No median vitta on the abdomen; ovipositor long and slender (Fig. 18*b*), about 5.5–6.0 mm. in length 16

16. Abdominal segments 3 to 5 chiefly black, rufous only in central portion; fifth tergum with a large brown to black spot on each side; the dark-colored vittae of the mesonotum narrow and the median portion of the dorsum broadly rufous . . . . *kraussi* n. sp.

Segments 3 to 5 rufous except for a narrow basal band on the third tergum; no dark-colored spot on the fifth tergum; the black vittae of the mesonotum broad and separated by just a narrow reddish line down the middle of the dorsum (some specimens may run here). . . . *musae* (Tryon)

17. Abdomen with a black vitta extending longitudinally down the middle over terga 3 to 5; sides of abdomen rufous. . . . .*pallidus* (Perkins and May)

Central portion of abdomen pale, no black vitta present; sides brownish to black. 18

18. Abdomen predominantly black, third tergum all blackish; costal cells slightly yellowish; female ovipositor elongate, the visible portion is equal in length to the last two or three abdominal segments (Fig. 20*b*) (some specimens key here). . . . *kraussi* n. sp.

Abdomen chiefly rufous, third tergum brown to black only on the sides;

costal cells milky-white; ovipositor short and inconspicuous, the visible portion only about half as long as the fifth segment (Fig. 11*a*)...... ....*barringtoniae* (Tryon)

19. Mesonotum with a median yellow postsutural vitta; costal band expanded at tip into a conspicuous apical spot.......*cucurbitae* Coquillett

No median yellow vitta on mesonotum; costal band not expanded at apex.......................... 20

20. Only the r–m crossvein infuscated... ....*laticaudus* Hardy

With a complete crossband over the middle of the wing.............. 21

21. An S-shaped band in the wing, extending over the r–m crossvein straight across the middle of cell 1st M_2 to the wing margin, back along the m crossvein, and out to the wing apex along vein M_{1+2}... ....*manskii* (Perkins and May)

Crossband extending over center of wing, not S-shaped or extending along M_{1+2} beyond m crossvein..22

22. Costal cells dark brown-fumose, very densely covered with microtrichia; notopleural calli yellow; r–m crossvein two times its own length from the m crossvein.......*pulcher* (Tryon)

Costal cells hyaline, devoid of microtrichia except in apex of second cell; notopleural calli brown; r–m crossvein less than its own length from the m crossvein......*strigatus* (Perkins)

Dacus (Strumeta) barringtoniae (Tryon)

Fig. 11*a*, *b*

Strumeta barringtoniae Tryon 1927. Roy. Soc. Queensland, Proc. 38: 196–197.

This species is distinguished by its very short and broad ovipositor, its pale reddish to yellow thorax, and by the lack of a median vitta on the abdomen. It is most closely related to *D. breviaculeus* n. sp., but is easily separated by the characters noted above as well as by a comparison of the female ovipositors (Figs. 11*b* and 12*c*).

MALE. Predominantly pale species with brown to blackish markings only on the sides of the abdomen and sometimes on the pleura. *Head:* The frontal and the occipital bristles are dark brown to black, the other head bristles are brownish-red to yellow-red. There are two pairs of inferior fronto-orbital bristles. The front is nearly two times longer than wide and is but slightly discolored in the median part. The area around the bases of the frontal bristles is not discolored. The facial spots are large, almost circular, and extend to near the oral margin. The third antennal segment is brown to blackish on the inner dorsal surface. The third segment is about one and one-third times longer than the face (measured on a mid-line) and is nearly five times longer than wide. *Thorax:* Scutellum, humeri, etc., yellow, and with broad postsutural yellow vittae on the sides of the mesonotum. These vittae extend from the suture to just beyond the bases of the inner posterior supra-alar bristles. Except for the yellow markings the entire mesonotum is reddish in ground color. This ground color is partially obscured by dense gray pruinosity. This pruinosity is indistinctly divided by three subshining lines running longitudinally the full length of the thorax; one of these is median and the other two are submedian in position. The scutellum has a narrow brownish band at its base. The sternopleura and the anterior margins of the mesopleura are brown tinged. The yellow mark on the mesopleura is broad on the dorsal one-half to two-thirds of the sclerite and narrowed below. In the upper portion the spot covers three-fourths of the top margin of the sternopleuron. *Legs:* Entirely yellow except for the brownish discoloration on the hind tibiae. *Wings:* First two costal cells hyaline and devoid of microtrichia except in the apical portion of the second cell. Costal band and cubital streak distinct and brownish in color. The costal band is comparatively narrow but does extend a short way into cell R_3 and a short distance into cell R_5 at its apex. The cubital streak is broad and fills all of the

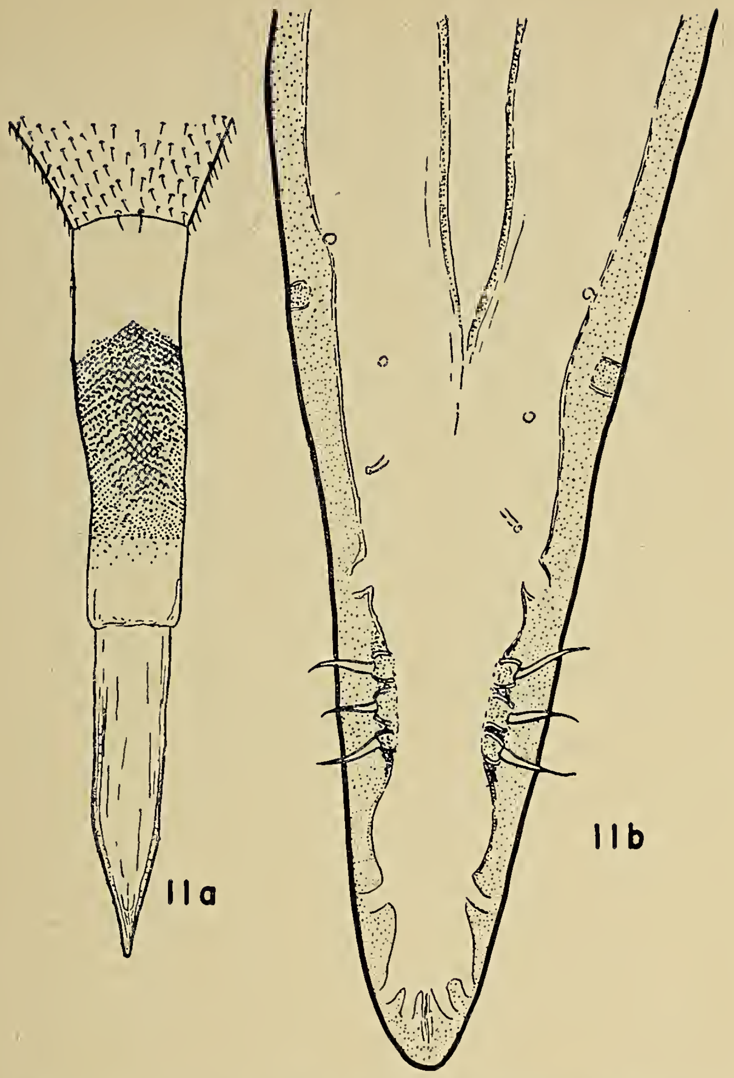

FIG. 11. *Dacus* (*Strumeta*) *barringtoniae* (Tryon): a, ovipositor, full length; b, apex of ovipositor.

basal part of cell M$_4$ extending almost to the top margin of the m–cu crossvein. The narrowed portion of the cubital cell is two times longer than the distance from the apex of the cell to the wing margin. *Abdomen:* Largely pale colored with no longitudinal vitta down the middle. The first tergum is brownish except for a narrow yellow band at its apex. The second tergum has a narrow yellow basal band followed by a brownish band and a broad pale yellow band which covers the apical half of the segment. Segments 3 and 4 are yellow in the middle and brown to blackish on the sides. The third tergum often has a complete but narrow brown to black basal band. The fifth tergum is entirely rufous except for brownish discolorations on the anterior lateral margins.

Length: Body, 7.8 mm.; wings, 6.8 mm.

FEMALE. The cubital streak extends slightly more than half way between the apex of cell Cu and the wing margin. The narrowed portion of cell Cu is only about one and one-fourth times longer than the distance from the apex of the cell to the wing margin. *Ovipositor:* Very short and inconspicuous. In pinned specimens the visible portion of the ovipositor is just slightly over one-half as long as the fifth abdominal segment. The extended ovipositor is short and stubby and comparatively broad (Fig. 11*a*). The ovipositor measures about 3.3 mm. The piercer (Fig. 11*b*) is approximately 1.0 mm. long by about 0.23 mm. wide and is sharply tapered from a point well before the apex of the oviduct. The apex of the oviduct is about 0.21 mm. from the tip of the piercer. The preapical setae are inconspicuous and all are approximately equal in size. The apical pair is located about 0.045 mm. from the tip of the piercer. This distance is just slightly greater than the length of the plate bearing the setae. The inversion membrane is approximately 1.22 mm. long by 0.34 mm. wide. The scales are large, conspicuous, and sharp-pointed. The rasper extends to within 0.28 mm. of the base of segment 8. The basal segment of the ovipositor is about 1.2 mm. long by 1.0 mm. at its widest point.

Length: Approximately the same as in the male.

TYPE LOCALITY: Cairns, Queensland, ex *Barringtonia calyptrata.*

Type in the Queensland Museum.

Forty-five specimens are in the Krauss collection from Cairns, Queensland, ex *Barringtonia calyptrata*, Dec., 1949–Jan., 1950.

Dacus (Strumeta) breviaculeus n. sp.

Fig. 12*a–c*

This species is closely related to *D. barringtoniae* (Tryon) because of the very short inconspicuous ovipositor of the female and the predominantly pale body. It is distinguished by differences in the female ovipositors, as illustrated in Figures 11*b* and 12*c*; by the presence of two distinct brownish to black vittae on the mesonotum; by the smaller size; and by the presence of an indistinct to distinct median brown to black vitta on abdominal terga 3 and 4.

The species also appears to be related to *D. mayi* new name. It is readily separated from *D. mayi* and other related species by the marked differences in the female ovipositors (Figs. 12*c* and 20*a*), by the narrow costal band, by the lack of a median dark-colored vitta down the mesonotum, by the lack of the brown shining spots and median vitta on the fifth tergum, and by the predominantly pale coloration of the abdomen.

MALE. *Head:* Entirely yellow to reddish except for the shining black facial spots and for a slightly brownish discoloration in the middle of the front and sometimes at the bases of the frontal bristles. The front is two times longer than wide. The frontal spots are large, oblong, and slightly pointed below. All of the head bristles are dark brown to black. There are two pairs of inferior fronto-orbital bristles. The third antennal segment is brownish to black tinged on the upper surface, it is distinctly longer than the face (measured on a mid-line), and is three and one-half times longer than wide. *Thorax:* Chiefly yellowish to reddish with some dark brown to black markings on the pleura and mesonotum. With yellow, yellowish-white, or cream-colored humeri, scutellum, postsutural lateral stripes, and other areas typical of most members of this group. The base of the scutellum does not have a conspicuous brown to black band. The lateral yellow vittae extend from the suture to the postalar bristles. Between the lateral vittae are a pair of submedian brown to black stripes extending longitudinally, between the prescutellar and the postalar bristles, from the scutellum to the anterior margin of the thorax between the inner and outer scapular bristles (Fig. 12*a*). The stripes are expanded on the posterior portion in front of the scutellum, are briefly interrupted at the suture, and are expanded laterally in back of the humeri. The median portion of the mesonotum, between the black stripes, is clear yellow in

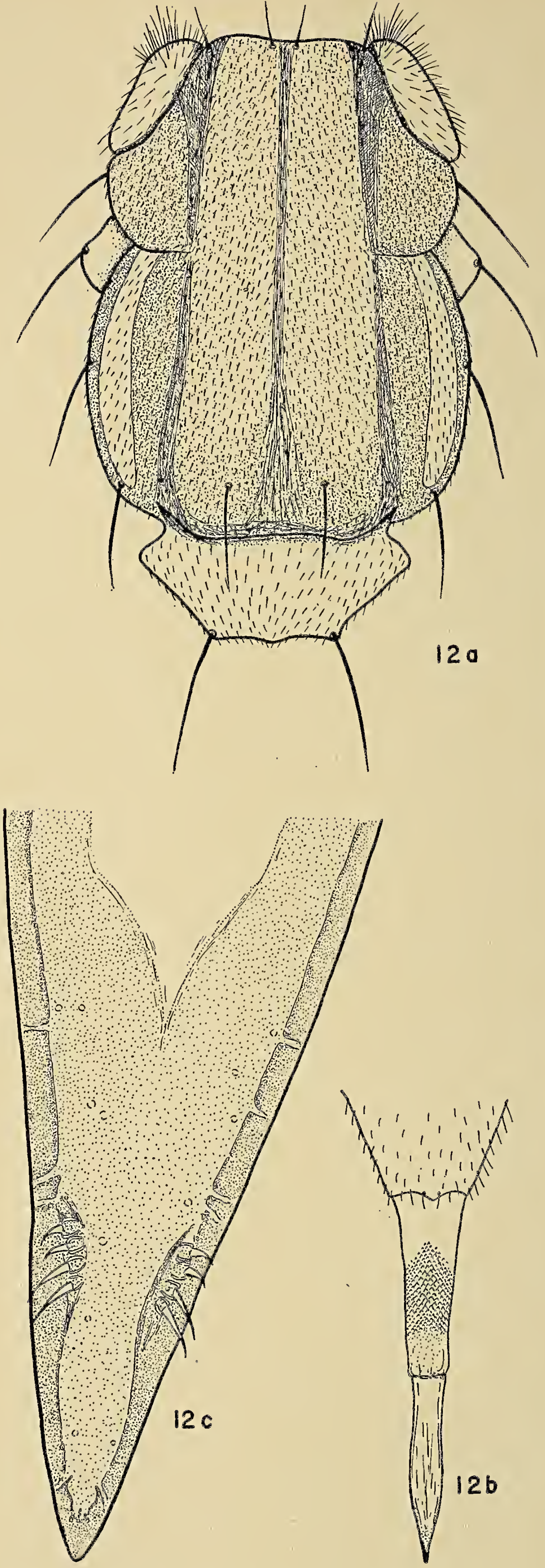

FIG. 12. *Dacus* (*Strumeta*) *breviaculeus* n. sp.: a, thorax, dorsal view; b, ovipositor, full length; c, apex of ovipositor.

ground color (well differentiated from the cream markings of the thorax), and is covered with gray pruinosity except for a shining vitta down the middle extending the full length of the thorax. The bristles are reddish-brown to black. The halteres are pale yellow. *Legs:* Chiefly yellow. The hind tibiae are tinged with brown to black. *Wings:* Chiefly hyaline, with a distinct but narrow costal band and a broad cubital streak. The first two costal cells are hyaline to very faintly yellowish and are devoid of microtrichia except in the apical part of the second costal cell. The costal band does not extend noticeably below vein R_3 except in the apical part of cell R_3. The band extends a short distance into cell R_5 at its apex. The r–m crossvein is straight, without a noticeable curve. The cubital streak fills all of the basal part of cell M_4 nearly to the top margin of the m–cu crossvein. The narrowed portion of the cubital cell is two times longer than the distance from the apex of the cell to the wing margin. *Abdomen:* Predominantly yellow with dark brown to black on the sides. The first tergum is largely brown with a narrow yellow-red apex. The second tergum has a narrow yellow-red band across the base, followed by a brown to black band, and by a broad yellowish band which occupies the apical half. The third tergum has a black band across the base and the sides are broadly black. The median portion has a very faint, brownish vitta extending over it. In some specimens this is very distinct and extends over segment 4. The fourth tergum is broadly yellow in the central portion (except as noted above) and blackish on the sides. The fifth tergum is largely yellow except for narrow brownish lateral margins.

Length: Body, 6.0 mm.; wings, 5.2 mm.

FEMALE. The cubital streak fades out about halfway along vein Cu_1 and 1st A. The narrowed portion of the cubital cell is one and one-third times longer than the distance from the apex of the cell to the wing margin. *Ovipositor:* Extremely short, scarcely noticeable in *in situ* specimens. From a dorsal view the visible part of the ovipositor is usually less than half as long as the fifth abdominal segment. When the ovipositor is fully extended (Fig. 12*b*) it measures approximately 2.5 mm. in length. The piercer is about 0.75 mm. long by 0.12 mm. wide. Four pairs of setae are conspicuous (Fig. 12*c*), the two distad pairs are about twice as well developed as the basal pair. The setae are situated about 0.055 mm. from the apex of the piercer, measured from the bases of the apical pair. This is slightly more than three times the length of the plate bearing the setae and four times longer than the longest setae. The piercer is just slightly more than six times longer than its greatest width and is gradually tapered beyond the apex of the oviduct (Fig. 12*c*). The oviduct extends to within 0.13 mm. from the tip of the piercer. The inversion membrane is about 0.83 mm. long by 0.2 mm. wide. The scales of the rasper are large, conspicuous, diamond-shaped, and extend to within 0.2 mm. of the base of the eighth segment. The basal segment is about 0.9 mm. long, measured on a mid-line, by 0.75 mm., measured across its hind margin. The spiracles are 0.13 mm. from the base of the segment, measured on the lateral margins.

Length: Approximately the same as in the male.

Holotype male, allotype female, and 12 paratypes (6 males and 6 females): near Atherton, Queensland, Dec., 1949, ex *Glochidion harveyanum*. Two male paratypes: Cairns, Queensland, Aug., 1949, same host as type.

Type, allotype, and two paratypes deposited in the United States National Museum. Three paratypes are in the Bishop Museum collection, Honolulu, T. H.; three are in the Board of Agriculture and Forestry collection, Honolulu, T. H.; three are at the Hawaiian Sugar Planters' Association; and three are in the University of Hawaii collection.

Three specimens, one female and two males, which apparently belong here, were in the collection from Cairns, ex guava, Apr., 1950. The ovipositor is just slightly longer but is structurally the same.

Dacus (Strumeta) bryoniae (Tryon)

Fig. 13*a*, *b*

Chaetodacus bryoniae Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 192.

This species is easily separated from other Australian species of *Dacus* by the broad costal band, the yellow costal cells nearly devoid of microtrichia, and the characteristic development of the female ovipositor.

MALE. Comparatively large, chiefly black-bodied species. *Head:* All rufous except for the shining black facial spots and the ocellar triangle. The median portion of the front and the bases of the frontal bristles are just slightly discolored with brownish. The front is parallel sided and is one and one-half times longer than wide. There are two pairs of inferior fronto-orbital bristles. The facial spots are circular to oval and are equal in length to about one-fourth the length of the face. The antennae are reddish, tinged with brownish on the third segment. The second segment is nearly two times longer than the first and is nearly half as long as the third. The third segment is about four times longer than broad. All of the head bristles are dark brown to black. *Thorax:* Dorsum all black except for the usual yellow markings which include two rather broad postsutural vittae. The median portion of the mesonotum is grayish pubescent, indistinctly divided into four parts by three narrow subshining longitudinal lines. The lateral yellow vittae extend from the suture to the inner supra-alar bristles. The base of the scutellum has a narrow black band. The metanotum is black, sometimes reddish in the central portion. The yellow vertical stripe on the mesopleura is broad and nearly parallel sided. *Legs:* All yellowish, except for brownish coxae, hind tibiae, and apical subsegments of tarsi. *Wings:* First two cells of the costa distinctly yellow-fumose but devoid of microtrichia except in the apical portion of the second cell. The costal band fills all of cell R_3 and extends a short distance below vein R_{4+5} along its entire length. At the apex of the wing the band extends broadly below R_{4+5} about one-third the distance to vein M_{1+2}. The cubital streak is broad; it fills all of the basal section of cell M_4 and extends nearly to the top margin of the m–cu crossvein. The narrowed portion of the cubital cell is about three times longer than the section from the apex of the cell to the wing margin. *Abdomen:* Chiefly reddish with a broad basal band on the third tergum, a subbasal black band on tergum 2, and a narrow black line running longitudinally down the middle of terga 3 to 5; this sometimes extends but a short distance onto the fifth tergum. The first tergum is discolored with brown to black, at least on the basal portion.

Length: Body, 7.8–8.0 mm.; wings, 7.0–7.2 mm.

FEMALE. The narrowed portion of the cubital cell is about one and one-fourth times longer than the distance from the apex of the cell to the wing margin. *Ovipositor:* Short and inconspicuous; in pinned specimens the visible portion of the ovipositor is shorter than the fifth abdominal segment. The extended ovipositor (Fig. 13*a*) is about 5.3 mm. in length and is very broad compared to its length. The piercer and the inversion membrane both measure about 1.9 mm. in length. The piercer is broadest just behind the tip of the oviduct and at this point measures about 0.3 mm. in width. The apex of the oviduct is approximately 0.45 mm. from the tip of the piercer, and the piercer tapers gradually from this point to a blunt tip. The setae are very tiny, inconspicuous (Fig. 13*b*), and difficult to see. There appear to be three setae on each side located about 0.22 mm. from the apex of the piercer. The inversion membrane is 0.6 mm. wide at its broadest point. The scales of the rasper are small, very numerous, and blunt at apices; they extend all the distance to the apex and to within

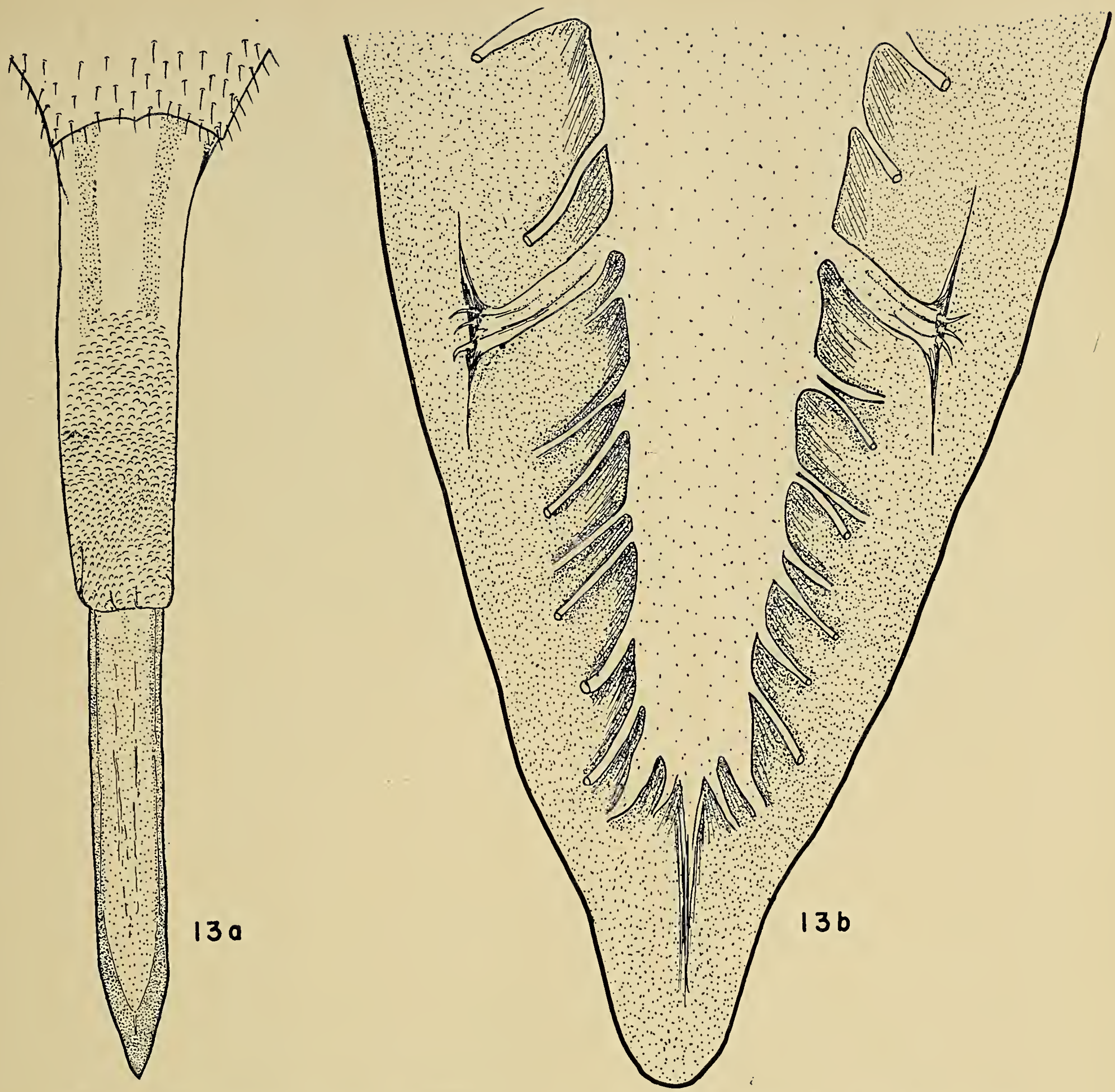

FIG. 13. *Dacus* (*Strumeta*) *bryoniae* (Tryon): a, ovipositor, full length; b, apex of ovipositor.

about 0.65 mm. of the base of the eighth segment.

TYPE LOCALITY: Blackall Range, Brisbane District. Reared from *Bryonia lacinosa*.

Type in the Queensland Museum.

Six specimens are in the collection reared from the above host, from near Deeral, Queensland, June, 1949. Tryon says it is also associated with *Melothria cunninghamii*.

Dacus (Strumeta) cacuminatus (Hering)

Fig. 14*a–e*

Strumeta cacuminata Hering 1941. Mus. Nat. Hung., Ann. 34: 46–47.

Chaetodacus dorsalis Tryon, nec. Hendel, 1927. Roy. Soc. Queensland, Proc. 38(14): 194–196.

Strumeta solani Perkins and May 1949. Univ. of Queensland, Dept. Biol. 2(14): 14–16.

This species has been treated many times in the Australian literature and much confusion has been centered around its nomenclature. It has commonly been known as the "Solanum fly" because of its apparent host specificity for two species of *Solanum*. It has appeared in the literature under the specific names *dorsalis*, *ferrugineus*, *tryoni*, and *solani*. The name *solani* was used by several of the earlier workers (Jarvis, 1922 and 1926*b*; Froggatt, 1924; Perkins and Hardy, 1925) in

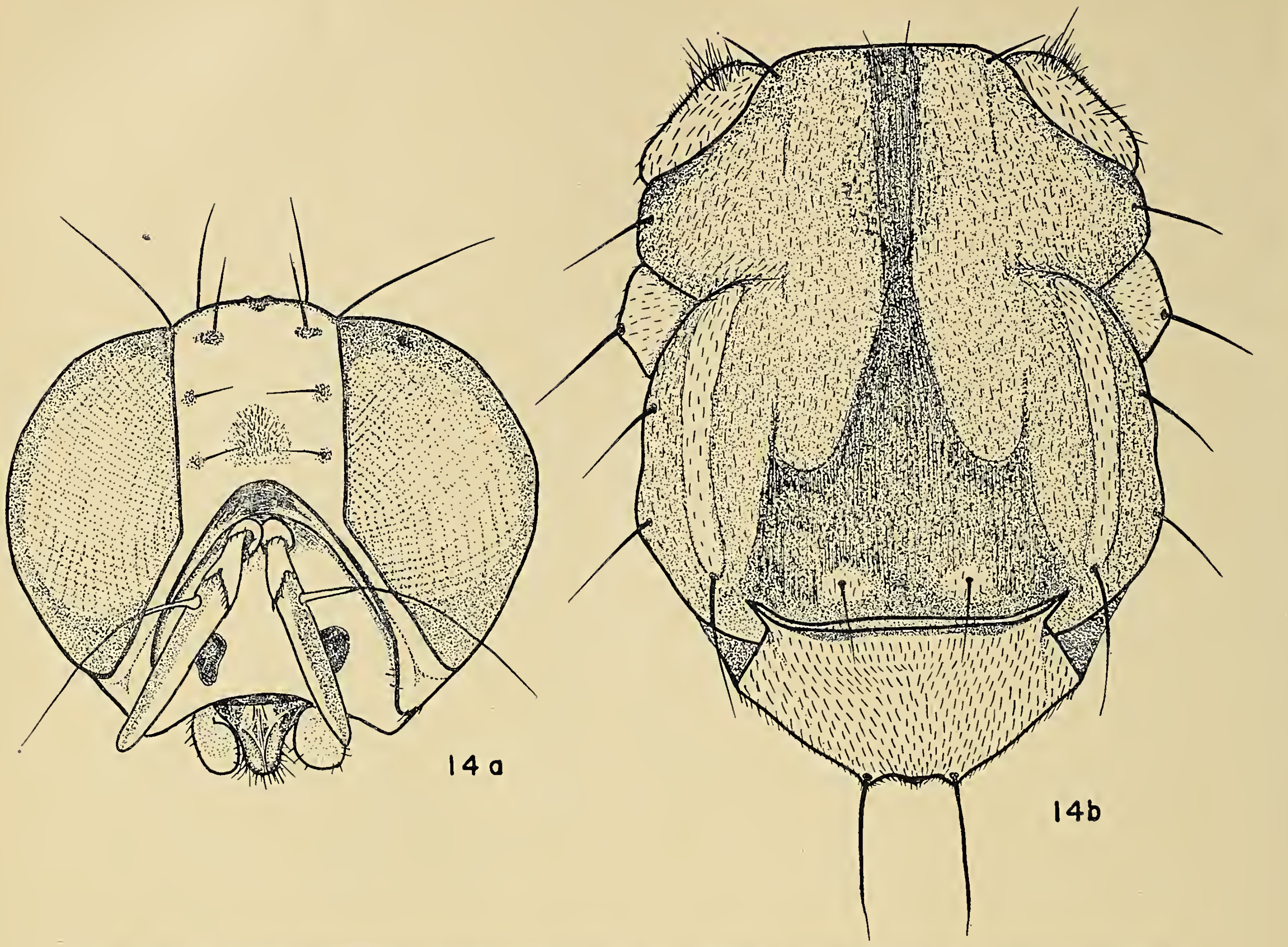

FIG. 14A. *Dacus* (*Strumeta*) *cacuminatus* (Hering): a, head of male, front view; b, thorax, dorsal.

a varietal sense under the names *Dacus tryoni* and *Dacus ferrugineus*. Tryon (1927) cited the name "*O. solani* Tryon mss. = *C. dorsalis* Hend." (The "O" was no doubt a typographical error.) The name *solani* was a manuscript name of Tryon's but was a *nomen nudum* until Perkins and May (1949) described as new the "Australian *dorsalis*" under the name *Strumeta solani*.

D. cacuminatus was confused with *D. dorsalis* Hendel in much of the more recent literature, and evidently Hering's description (1941*a*) was overlooked by the Australian workers. The species is related to *D. dorsalis* but is readily separated by a number of characteristics. The black mesonotal pattern is consistently different. It is represented by a rather narrow median line extending the full length of the thorax. This median line gradually widens behind the suture and expands broadly over the posterior portion of the mesonotum (Fig. 14*b*). The area around, and posterior to, the prescutellar bristles is often reddish, and the basal portion of the black pattern is sometimes almost Y-shaped. A pair of thin brown to blackish vittae is usually present, extending cephalad from the lateral edges of the black pattern and ending before the suture or extending as two faint lines to the inner edges of the humeri. The black median line is apparently a constant character. It has been present on all of the several thousand specimens which I have examined. In the color variations of the true *dorsalis* the mesonotal pattern apparently never breaks down into a median vitta with an expanded base. In *D. cacuminatus* the yellow vittae on the mesonotum end at the inner supra-alar bristle and at the suture. They do not extend beyond the bristles and into or along the suture as they do in *D. dorsalis*. The vittae are broadest on their an-

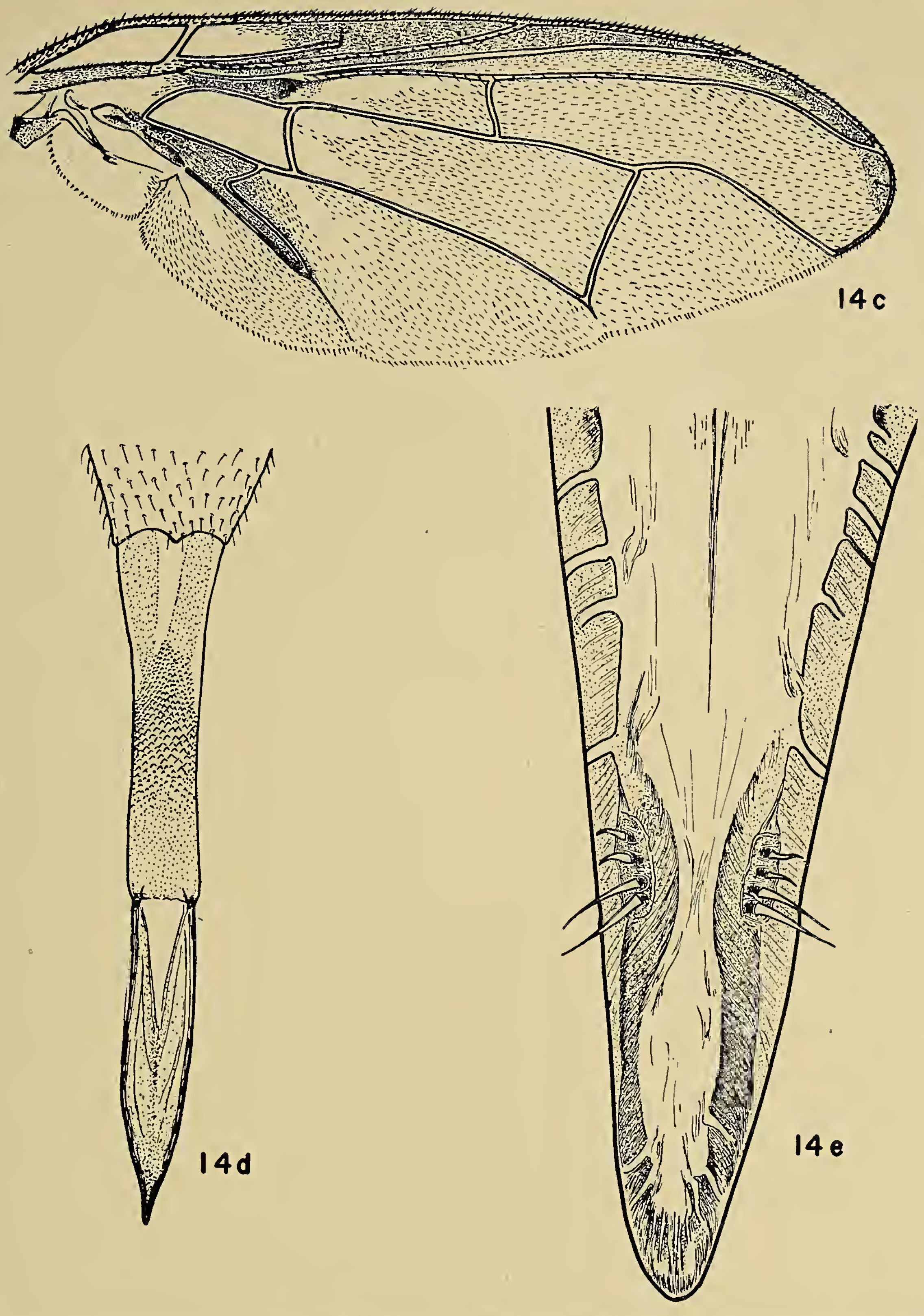

FIG. 14B. *Dacus* (*Strumeta*) *cacuminatus* (Hering): c, wing of female; d, ovipositor, full length; e, apex of ovipositor.

terior portions and narrowed posteriorly—not broad at both ends and parallel sided as in *dorsalis*. The prescutellar bristles are more widely spaced in *cacuminatus*; the distance between the bristles is equal to slightly greater than the distance between the scutellars. In *dorsalis* the prescutellars are slightly closer together than the scutellars. The wings are very similar to *dorsalis*, differing chiefly in having a broader, more distinct cubital streak. The streak fills almost all of the basal portion of cell M_4, approximately to the hind margin of the m–cu crossvein (Fig. 14*c*). In *dorsalis* the streak fills only about the basal half of cell M_4. The basal section of the anal veins (possibly including the base of cubitus) is hyaline to faintly yellowish translucent in *cacuminatus*. In *dorsalis* this basal portion is opaque whitish to yellow. The color pattern of the abdomen differs somewhat from typical *dorsalis*, although the most constant difference appears to be the lack of a complete black band on the basal portion of the second tergum in *cacuminatus*. The female ovipositors provide excellent characters for separating these species. The ovipositor of *cacuminatus* is shorter and thicker, the rasper extends nearer to the base of segment 8, the apex of the oviduct and the setae on the piercer are farther from the apex of that segment, and the plate or section bearing the setae is very short compared to that of *dorsalis*. Following are the specific characteristics of the ovipositor of *cacuminatus*. In undissected specimens the visible portion of the ovipositor is about equal in length to the fifth tergum. When the ovipositor is fully extended (Fig. 14*d*), it measures about 3.7 mm. in length. The piercer is about 1.2 mm. by about 0.25 mm. at its widest point. The apex of the oviduct is about 0.2 mm. from the apex of the piercer. The setae are inconspicuous and are situated about 0.07 mm. from the apex of the segment. This distance is equal to four times the length of the plate bearing the setae or the length of the longest setae (Fig. 14*e*). The inversion membrane is about 1.3 mm. long by 0.3 mm. at its broadest point. The scales of the rasper extend to within 0.32 mm. of the base of the segment. The basal segment is about 1.2 mm. long, and the spiracles are 0.33 mm. from the posterior lateral margins of segment 7.

Length: Body, 6.0–7.0 mm.; wings, 5.5–6.4 mm.

TYPE LOCALITY: Brisbane.

Type in the Musei Nationalis Hungarici, Budapest.

This species has been recorded from numerous localities in Australia. It is chiefly associated with the two common species of wild tobacco, *Solanum verbascifolium* Ait. and *S. auriculatum* Ait.

A large number of specimens are in the collection from Atherton Tableland, Queensland, June to Nov., 1949, ex the fruits of these two species of *Solanum*. One specimen is at hand, ex *Rhipogonum papuanum* near Atherton, Queensland, Nov., 1949. This is the first record of this species infesting fruits other than those of solanaceous plants. It is possible that the record is an error.

Dacus (Strumeta) endiandrae
(Perkins and May)
Fig. 15*a*, *b*

Strumeta endiandrae Perkins and May 1949. Univ. of Queensland, Dept. Biol. 2(14): 9–10.

This species is related to *D. musae* (Tryon) and is separated by the presence of a longitudinal black vitta down the middle of the abdomen and by the differences in the female ovipositors as illustrated in Figures 15*a* and 21*b* and as given under the discussions of the ovipositors. *D. endiandrae* is very similar to *D. dorsalis* Hendel and should be considered in this complex of species. In general characteristics and coloration it is much like *D. dorsalis* and is evidently the nearest thing to this species that occurs in Australia. *D. endiandrae* is distinguishable from *dorsalis* by the broad cubital streak and more elongate cubital cell in the wing. Comparison of the female ovipositors shows close relationship, but specific differences are evident. The piercer is shorter in *endiandrae*, the setae are farther from the apex of the ovipositor, and the scales of the rasper extend nearer to the base of segment 8 than they do in *dorsalis*.

Except for the female ovipositor, the species has been adequately described by Perkins and May, and the following are the diagnostic characteristics of both sexes. *Head:* The front is nearly two times longer than wide and has two pairs of inferior fronto-orbital bristles. The facial spots are oval and somewhat pointed on the lower margin. *Thorax:* Predominantly black, especially on the dorsum. Mesonotum often with a reddish spot between the prescutellar bristles; in some specimens this extends part way down the dorsum as a narrow median vitta. The scutellum has a narrow black band at its base. The prescutellar bristles are the same distance apart as the scutellars. *Wings:* The two costal cells are hyaline and devoid of microtrichia except in the apical portion of the second section. The costal band is comparatively narrow but does extend faintly along the underside of vein R_3. The costal band extends a short distance beyond the apex of vein R_{4+5}, about one-third the distance across the apex of cell R_5. The cubital streak is moderately broad and fills the basal portion of cell M_4 up to the lower margin of the m–cu crossvein. In the male the narrowed portion of cell Cu is two times longer than the distance from its apex to the wing margin. In the female the narrowed portion of Cu is one and one-third times longer than the distance to the wing margin. *Abdomen:* Colored as in *dorsalis* with the first tergum chiefly dark colored, the second yellow-white on the apical half and with a subbasal brown to black crossband; a black longitudinal median vitta extends down terga 3 to 5 and a broad basal band of black is on the third tergum. *Ovipositor:* Comparatively short, rather inconspicuous in pinned specimens. The extruded portion of the ovipositor is usually about equal in length to the fifth tergum. The extended ovipositor (Fig. 15*a*) is about 3.6 mm. in length. The piercer measures approximately 1.2 mm. long by 0.19 mm. wide at its broadest point. The setae are well developed and are located about 0.065 mm. from the apex of the piercer. This distance is equal to four times the length of the plate bearing the setae or to the length of the longest setae (Fig. 15*b*). The piercer tapers gradually from a point in front of the apex of the oviduct. This apex is about 0.22 mm. from the tip of the piercer. The inversion membrane is 1.4 mm. long by 0.22 mm. at its widest point. The scales of the rasper extend to within 0.45 mm. of the base of the eighth segment. The basal segment is about 1.2 mm. long on a mid-line by 1.0 mm. across its hind margin. The spiracles are located about 1.9 mm. from the base of the seventh segment measured on the lateral margins.

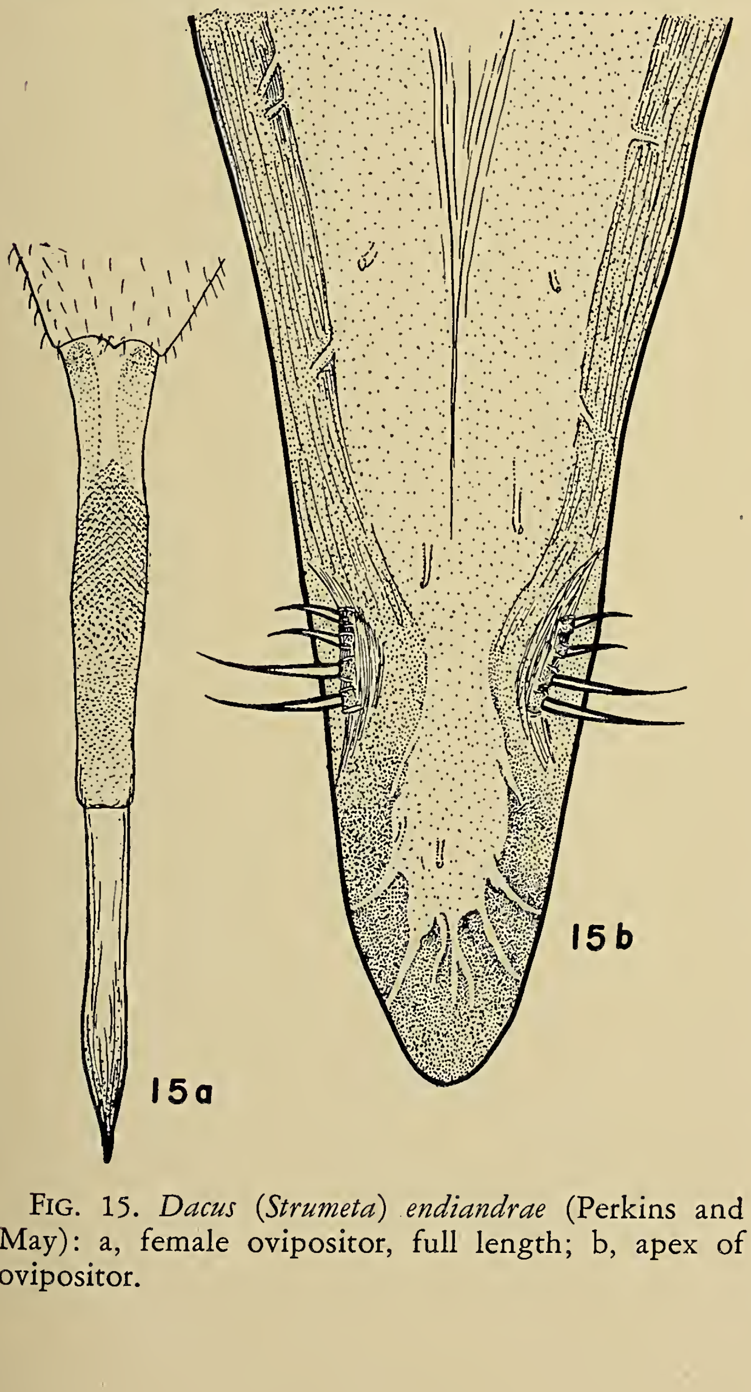

FIG. 15. *Dacus* (*Strumeta*) *endiandrae* (Perkins and May): a, female ovipositor, full length; b, apex of ovipositor.

Length: Body, 5.8–6.5 mm.; wings, 5.1–5.9 mm.

TYPE: No type or type locality designated. Described from a series bred from *Endiandra discolor* and *Cryptocarya erythroxylon* at Cairns and Mossman, Queensland.

Location of cotypes: University of Queensland.

A large series of specimens is in the Krauss collection from the following localities and hosts: near Deeral, Queensland, ex *Endiandra tooram*, July, 1949; Atherton Tableland, Queensland, ex same host, Nov., 1949; Cairns, Queensland, ex "Oval, dark purple fruit, ¾″ long," Nov., 1949; Babinda, Queensland, ex "dark purple fruit, 1″ long–⅝″ diameter," Nov., 1949; Atherton Tableland, ex *Beilschmiedia obtusifolia*, Nov., 1949; and Atherton Tableland, ex *Litsea leefeana*, Nov., 1949. Two specimens were also mixed in with a large series of *Dacus kraussi* n. sp. from Deeral, ex *Acmena macrocarpa*, June, 1949. These may have been included in this series by accident.

Dacus (Strumeta) fagraeus (Tryon)

Fig. 16*a*, *b*

Chaetodacus fagraea Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 188–190.

This species is very characteristic and is easily recognized by its pale color, its very elongate female ovipositor, and by the pointed facial spots.

MALE. *Head:* The front is about two times longer than wide, with distinct brownish spots at the bases of the frontal bristles and brownish on the tumescence. Two pairs of inferior fronto-orbital bristles are present. The facial spots are large and conspicuous and have the underside drawn out into a sharp point which extends almost to the oral margin. The third antennal segment is brownish and is slightly longer than the face and about four times longer than wide. *Thorax:* Reddish except for the usual yellow markings; no dark marks. *Legs:* Entirely reddish to yellow, hind tibiae sometimes brownish tinged. *Wings:* The first two costal cells are hyaline to very faintly yellowish, devoid of microtrichia except in the apical portion of the second cell and the top margin of the first cell. The costal band is moderately developed. It extends faintly along the underside of vein R$_3$ and ends in the wing apex just beyond R$_{4+5}$. The cubital streak is broad and fills all of the basal part of cell M$_4$, extending nearly to the top edge of the m–cu crossvein. The narrowed portion of the cubital cell is about three times longer than the portion from the apex of the cell to the wing margin. *Abdomen:* Entirely rufous with no distinct brown to black markings.

Length: Body, 6.5–7.0 mm.; wings, 6.0–6.5 mm.

FEMALE. The fifth tergum sometimes has a faint brownish median vitta. The narrowed portion of the cubital cell is nearly two times longer than the distance from the apex of the cell to the wing margin. *Ovipositor:* Always conspicuous; because of its unusual length it cannot be drawn in out of sight. The extended portion in specimens *in situ* is equal to or greater than the combined lengths of abdominal segments 3 to 5. The extended ovipositor (Fig. 16*a*) is equal to or longer than the remainder of the body; it is approximately

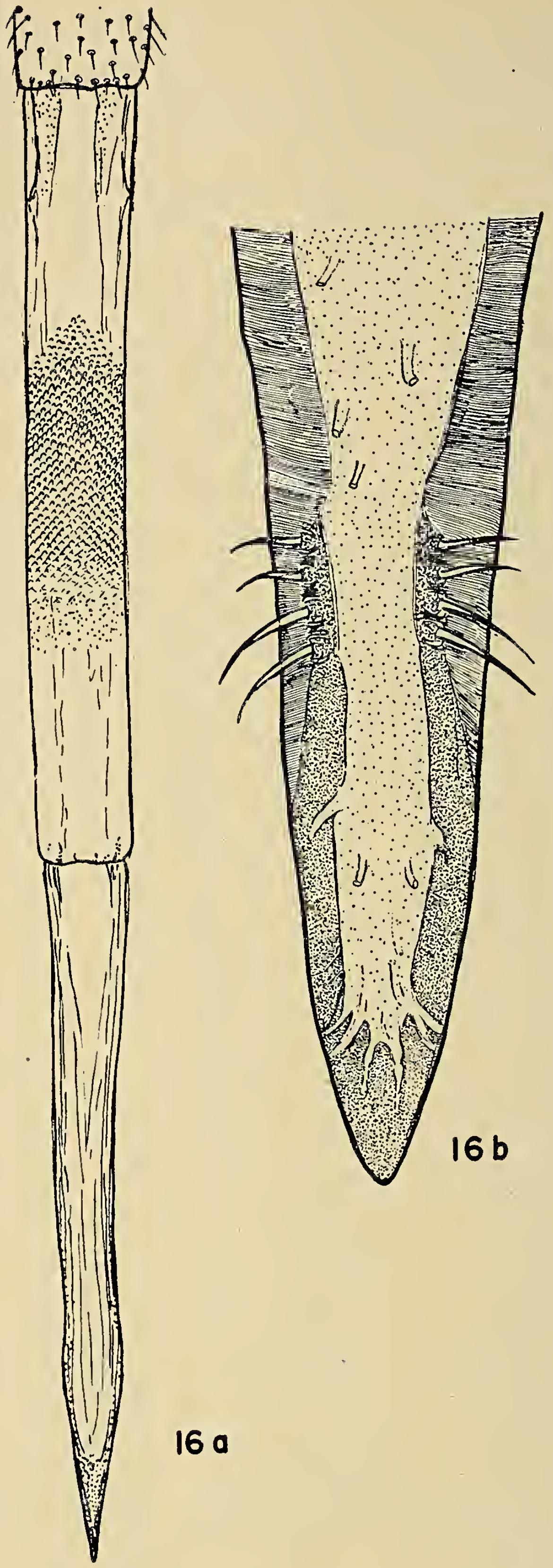

FIG. 16. *Dacus* (*Strumeta*) *fagraeus* (Tryon): a, ovipositor, full length; b, apex of ovipositor.

7.0 mm. long. The piercer (Fig. 16*b*) is about 2.4 mm. long by 0.19 mm. wide. The end of the oviduct is about 0.23 mm. from the apex of the piercer, and the setae are situated about 0.09 mm. from the apex. The inversion membrane is approximately 2.6 mm. long by 0.34 mm. wide. The scales of the rasper are pointed and extend to about 0.85 mm. from the base of the eighth segment. The basal segment of the ovipositor is elongate and is noticeably constricted on its apical two-fifths. The basal segment is about 2.1 mm. long by 1.35 mm. at its widest point. The spiracles are located about 0.38 mm. from the base of the segment.

TYPE LOCALITY: Babinda, N. E. Queensland, ex *Fagraea mulleri* Benth.

Type in the Queensland Museum.

Approximately 150 specimens are in the Krauss collection from near Deeral, Queensland, ex *Fagraea cambogeana*, Sept., 1949. Four specimens are from Babinda, Queensland, ex *Eugenia* sp. near *suborbiculata*, Sept., 1949.

Dacus (Strumeta) halfordiae (Tryon)

Fig. 17*a*, *b*

Chaetodacus halfordiae Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 190–191.

Chaetodacus gurneyi Perkins 1934. Roy. Soc. Queensland, Proc. 45: 41–42. New synonymy.

This synonymy is based upon a close comparison of the original descriptions and upon a study of specimens from the type locality of *D. gurneyi* as well as from other localities in Queensland. The synonymy has been confirmed by Mr. Alan May.

This species is distinguished from other known Australian species of *Dacus* by the largely brownish disc of the scutellum, by the black spots on the fifth tergum, and by the characters of the female ovipositor. The general body coloring is similar to that of *D. tryoni* (Froggatt) and the costal cells are usually yellowish-fumose but are bare of microtrichia except in the apical portion of the second cell. The specimens at hand are not in good condition; one series is teneral and the others were preserved in alcohol and are badly discolored. Only the most important characteristics are given below.

MALE. Chiefly pale colored, yellow-brown to rufous. *Head:* Front about one and three-fourths times longer than wide, with two pairs of inferior fronto-orbital bristles. The facial spots vary somewhat in size and shape from oval to a narrow black streak; the spots are usually pointed on the lower margin. The third antennal segment is just slightly longer than the face and little more than three times longer than wide. *Thorax:* Varying from chiefly yellowish to rufous to yellow-brown. A brown to black vitta is usually present on each side, extending from just inside the inner posterior supra-alar to the margin of the

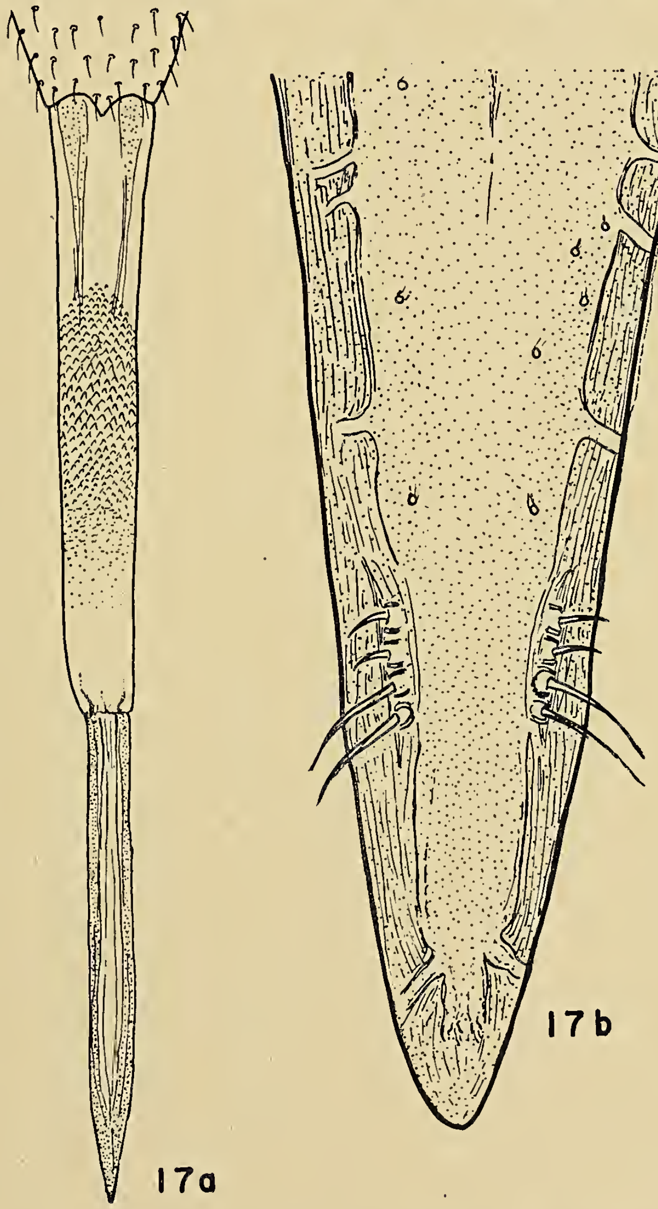

FIG. 17. *Dacus* (*Strumeta*) *halfordiae* (Tryon): a, ovipositor, full length; b, apex of ovipositor.

humerus; usually interrupted at the suture. The disc portion of the scutellum is brown, the margins are yellow. In teneral specimens the entire scutellum may be yellow. *Wings:* First two costal cells faintly yellow to almost hyaline, devoid of microtrichia except in the apical part of the second cell and sometimes along the extreme top margin of the first cell. The costal band is conspicuous but is not noticeably extended below vein R_3 except at its apex. The cubital streak is broad and fills all of the basal portion of cell M_4. The narrowed portion of the cubital cell is about two times longer than the free portion of vein Cu_1+1st A. *Abdomen:* Varying from yellow-brown to almost all yellowish, probably depending upon tenerality. The large brown to black lateral spots on the fifth tergum are very conspicuous.

Length: Body, 5.5–7.0 mm.; wings, 5.0–6.0 mm.

FEMALE. The narrowed portion of the cubital cell is about one and one-third longer than Cu_1+1st A. *Ovipositor:* Conspicuous and well developed; the exposed portion is about equal in length to segments 3 to 5 of the abdomen. The extended ovipositor (Fig. 17*a*) is approximately 5.0 mm. long. The piercer is about 1.56 mm. long by 0.15 mm. wide. The end of the oviduct is about 0.19 mm. from the apex of the piercer. The setae are situated about 0.02 mm. from the apex or about two times the length of the plate bearing the setae or the length of the longest pair. The apex of the piercer is rather blunt when viewed under high magnification (Fig. 17*b*). The inversion membrane is about 2.0 mm. long by 0.2 mm. wide, measured at its base. The scales are thorn-like and extend to within about 0.6 mm. from the base of the segment. The base of the ovipositor is about 1.46 mm. long by 1.0 mm. across its hind margin.

TYPE LOCALITY: Southport, South Queensland.

Type in the Queensland Museum.

Specimens were sent in by Mr. Krauss from Narara, New South Wales, Nov. 29, 1933, ex *Eugenia* sp. (coll. by C. P. Hely).

Dacus (Strumeta) kraussi n. sp.

Fig. 18*a–c*

This species occupies a borderline position between the group of species in which the first two sections of the costa are yellow-fumose and those species in which these cells are hyaline. *D. kraussi* is related to *D. tryoni* (Froggatt) and has probably been confused with that species. The most striking differences in the two species are in the female ovipositors. In *D. kraussi* the ovipositor is nearly two times longer than that of *D. tryoni*; moreover, it is much more slender and differs in several structural details. The first and second costal cells are subhyaline to lightly yellowish and are devoid of microtrichia except along the top margin of the first cell and the apical half of the second. In *D. tryoni* the costal cells are bright yellow-fumose and are densely covered with microtrichia throughout the second cell and the apical half and top margin of the first. In *D. kraussi*, cell R_5 (the apical cell) is expanded at its apex. Veins R_{4+5} and M_{1+2} are slightly divergent at their apices so that the cell is broader at the apex than at any other point; its width is equal to the length of the m crossvein. In *D. tryoni* the apical cell is not expanded at the apex; it is as broad at a point opposite the m crossvein as it is at the wing margin, and the width at the apex of the cell is less than the length of the m crossvein.

This species is also related to *D. barringtoniae* (Tryon). In the preliminary studies of this collection some of the specimens under this series were classified as "*barringtoniae?*" The species are easily separated by the comparatively elongate ovipositor of *D. kraussi* and the very short stubby ovipositor of *D. barringtoniae*, by the yellowish costal cells in *D. kraussi* and the milky white cells in *D. barringtoniae*, and by the predominantly black abdomen of *D. kraussi* with the third tergum

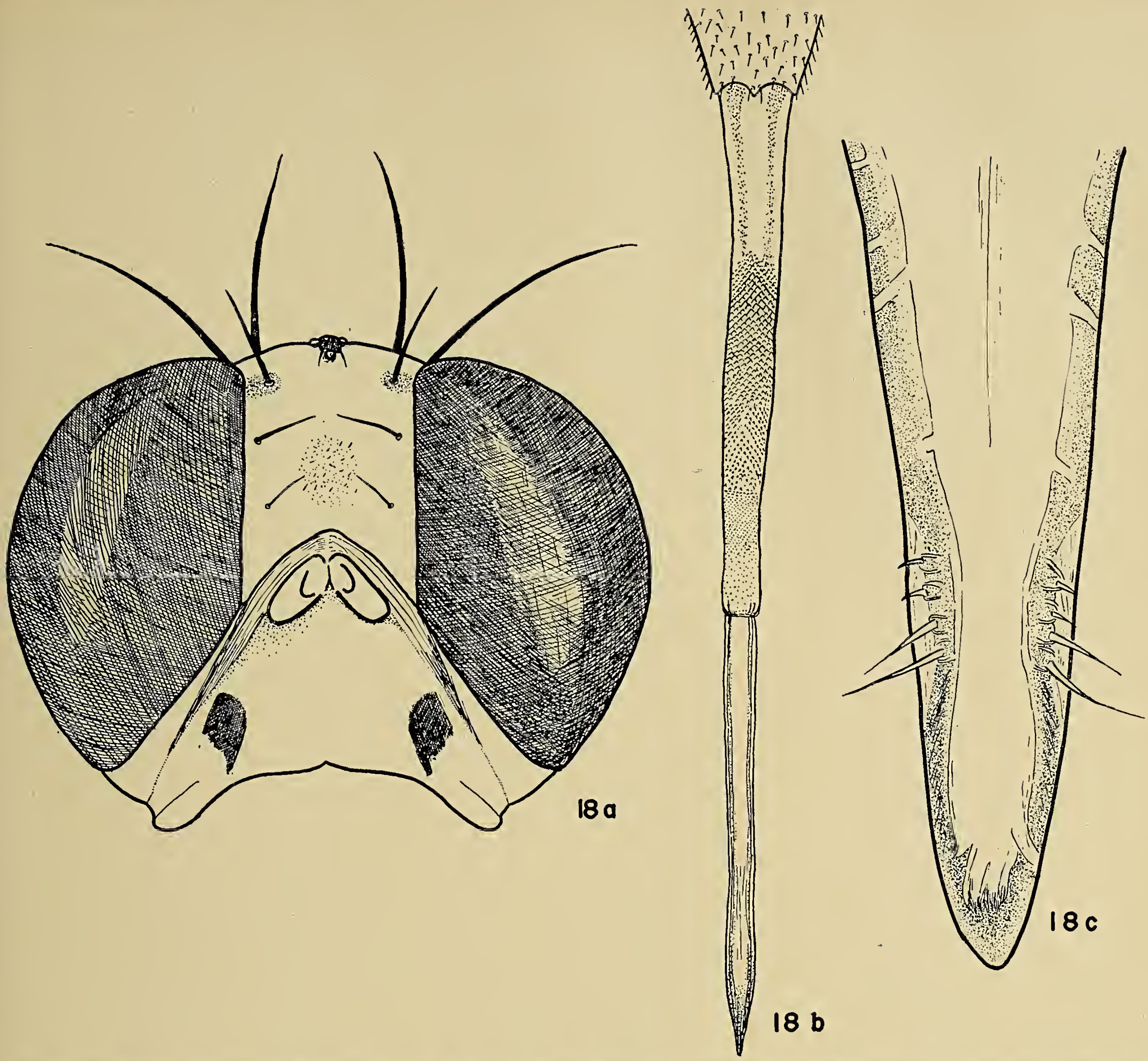

FIG. 18. *Dacus* (*Strumeta*) *kraussi* n. sp.: a, head, front view; b, ovipositor, full length; c, apex of ovipositor.

all black. In *D. barringtoniae* the abdomen is largely reddish with no black markings or crossbands.

MALE. *Head:* All rufous except for the shining black facial spots. The front is about two times longer than wide and is just slightly discolored in the median portion. Most of the head bristles are brownish-red, the fronto-orbital bristles are black. There are two pairs of inferior fronto-orbitals and one pair of superiors. The occiput is entirely pale. The facial spots (Fig. 18*a*) are moderately large, suboval in shape, and indistinctly pointed below; often drawn out into a distinct point as in *fagraeus*. *Thorax:* Chiefly rufous, with the usual pale yellow on the humeri, notopleura, etc., and with a yellow vitta on each side of the mesonotum from the suture to the posterior supra-alar bristles. The mesonotum has a narrow shining reddish-brown to blackish line extending down each side (inside the lateral yellow vittae) from the inner edge of each humerus to the scutellum. A median longitudinal vitta is also set off on the mesonotum by a subshining yellow-red line bisecting the grayish pruinosity which covers the dorsum. The bristles are typical of the subgenus. The metanotum is reddish-brown on the sides, yellowish in the middle. The mesopleural stripe is rather narrow and is not markedly expanded on the top portion and is scarcely broader than the notopleural calli. The halteres are clear yellow. *Legs:* All yellow except for brownish discolorations on the hind coxae. The spurs of the middle tibiae are reddish black. *Wings:* Costal band grayish-brown and distinct through the third and fourth sections of the costa (cells Sc and R_2) and along the costal border through the apex of cell R_3. The band actually extends through most of cell R_3 but is faint and not distinct below vein R_3. The band extends just a short distance into cell R_5. The cubital streak is broad and distinct brownish in color. It fills all of the basal portion of cell M_4, nearly to the top of the m–cu crossvein. The brown colored portion of the streak ends at about the apex of the cubital cell and blends into the typical gray to blackish coloring along vein Cu_1+1st A. The narrowed portion of cell Cu is slightly more than two times longer than the distance from the apex of the cell to the wing margin. A distinct lobe is present at the tip of Cu_1+1st A. There is no distinct spot present at the tip of vein M_{3+4}. Venation otherwise as given in the general discussion. *Abdomen:* Chiefly black or dark colored. The first tergum is brown to black on the basal three-fourths, with a yellow band across the apex. The second tergum has a brownish band across the basal one-third to one-half and is yellow to whitish on the apical portion. The third tergum is entirely shining black and has the usual row of black cilia on each side. The fourth tergum is broadly yellowish to slightly discolored brownish-yellow down the middle portion and shining black on the sides. The fifth tergum has a large shining black spot on each side; the median part and the apical one-third are all yellow.

Length: Body, 6.7 mm.; wings, 6.0 mm.

FEMALE. The brownish coloration of the cubital streak extends well beyond the apex of the cubital cell, about halfway to the wing margin. The cubital cell is about one and one-third times longer than the distance from the apex of the cell to the wing margin. *Ovipositor:* Reddish-yellow to brownish in color and very conspicuous. In undissected specimens the ovipositor extends beyond the apex of the fifth segment, a distance about equal to the combined lengths of segments 3 to 5. The basal segment of the ovipositor (segment 7) is distinctly longer than segment 5. The fully extended ovipositor is 6.0 mm. long (Fig. 18*b*). The piercer is about 2.0 mm. (Fig. 18*c*) by about 0.2 mm. wide and tapers gradually from a point well in front of the apex of the oviduct. The oviduct extends to within 0.2 mm. from the tip of the ovipositor. Four pairs of preapical setae, two long and two short, are well developed. The posterior pair is located slightly more than twice its length or approximately 0.064 mm. from the apex. The inversion membrane is 2.4 mm. long by about 0.29 mm. wide. The rasper extends to within about 0.85 mm. of the base of the segment (Fig. 18*b*). The basal segment is about 1.64 mm. long, measured on a midline, and the spiracles are located 0.32 mm. from the base of the segment, measured on the lateral margins.

Length: Approximately the same as in the male.

Holotype male and allotype female: Deeral, Queensland, ex *Acmena macrocarpa*, June, 1949. Approximately 500 specimens are on hand, same data as type; 300 are being designated as paratypes. Over 100 specimens are also on hand from the following localities and hosts: Cairns, Queensland, ex *Eugenia branderhorstii* and *E. tierneyana*, Jan.–Feb., 1950; Atherton Tableland, Queensland, ex *Schizomeria whitei*, *Eugenia luehmannii*, and *Endiandra compressa*, Nov., 1949, and March, 1950; Babinda, Queensland, ex *Arytera* sp.? Sept., 1949; Garradunga, Queensland, ex *Rhodomyrtus macrocarpa*, Nov., 1949, and ex *Eugenia suborbicularis*, Aug., 1949; Cairns, Queensland, ex *Psidium guajava*, June, 1949, and March, 1950; Atherton Tableland and Julatten, Queensland, ex *Castanospora alphandii*, Dec., 1949; near Oak Beach, North Queensland, ex *Thevetia peruviana*, Feb., 1950; Clump Point, Queensland, ex *Eugenia cormiflora*, July, 1949; also Cairns, same host as the last, Dec., 1949.

Holotype, allotype, and a series of paratypes are in the United States National Museum collection. Paratypes are also being deposited in the following collections: Bishop Museum, Honolulu, T. H.; Board of Agriculture and Forestry, Honolulu, T. H.; Hawaiian Sugar Planters' Association, Honolulu, T. H.; University of Hawaii, Honolulu, T. H.; American Museum of Natural History; California Academy of Sciences; University of Berlin (Dr. M. Hering); and the collection of H. K. Munro, Pretoria, South Africa.

Dacus (Strumeta) laticaudus Hardy

Strumeta fuscatus Perkins and May 1949. Univ. of Queensland, Dept. Biol. 2(14): 5–6. This name is preoccupied in *Dacus* by *D. fuscatus* Wiedemann 1819. Zool. Mag. 1(3): 28.

Dacus (*Strumeta*) *laticaudus* Hardy 1950. Haw. Ent. Soc., Proc. 14(1): 87–89. New synonymy. The name is available, however, since *fuscatus* Perkins and May is a homonym.

The description of *D. laticaudus* was published before I had seen Perkins and May's paper. From the original description of *fuscatus* Perkins and May it would appear that the two are distinct species distinguishable by several characters. Figure 2 of Perkins and May (1949) shows the r–m crossvein of *fuscatus* as being strongly sinuate. The crossvein in the specimens described as *laticaudus* is nearly straight. Perkins and May's description states that the abdomen is "entirely black except for dark brown area on posterior median portion of second tergite; ovipositor shiny dark brown . . . shiny spot on fifth tergite, black in female and brown in male." The large series of specimens at hand has a black longitudinal vitta extending down the middle of terga 3 to 5. The shining spots on the fifth tergum are rufous; the ovipositor is also pale colored. The original description of *fuscatus* also indicates that the mesonotum is extensively brown to black. It is predominantly rufous in the specimens of *laticaudus*.

I have received specimens of *D. fuscatus* (Perkins and May) from Mr. May, and he has also discussed the species in correspondence. He has reported that "the r–m crossvein in the type is not as sinuate as I have wrongly shown in my drawing. Although somewhat sinuate in the type male, for the type female the vein is almost straight." This is apparently a variable character. The median black vitta on the fourth and fifth terga is present on the specimens sent by Mr. May (this was not shown in his figure 2, or mentioned in the original description).

The species has been adequately described and figured in the publications mentioned above. The most distinctive characteristics of the species are the fumose r–m crossvein and the short stubby ovipositor of the female.

TYPE LOCALITY: Cairns, Queensland, ex *Sideroxylon obovatum*.

Type in the University of Queensland collection.

The specimens in the Krauss collection were from near Deeral, Queensland, ex *Planchonella* sp.

Dacus (Strumeta) manskii
(Perkins and May)
Fig. 19*a*, *b*

Strumeta manskii Perkins and May 1949. Univ. of Queensland, Dept. Biol. 2(14): 3–4.

This species is remarkably similar to *D. recurrens* (Hering) described from New Guinea. Apparently it is best distinguished by the chiefly rufous mesonotum. The writer sent specimens of *D. manskii* to Dr. Hering for comparison with the type of *D. recurrens*, which was deposited in the Hungarian Museum. The type was not available, but Dr. Hering studied the specimens and indicated that *manskii* is evidently a distinct species and can be separated by the following characters: The mesonotum is reddish-yellow in *manskii* and black with gray pollen in *recurrens*; the second abdominal tergum has a black crossband in *manskii* and only black spots in *re-*

currens; the black lateral spots on the hind border of the third tergum "not reaching" in *recurrens* (probably he means not continuous across the segment) and "in *manskii* reaching, continued on fourth and fifth terga." He says also that *manskii* differs by lacking the brown spot at the lower eye margin and in having shorter wings ("wing 5 mm. [in *recurrens*] and 3.6 mm. in *manskii*"). The brown spots are usually present below the eye margin, and all the specimens of *manskii* on hand have a wing length of 5.0–5.4 mm. The coloration of the thorax shows some variation, and some specimens have extensive black markings on the dorsum as well as on the pleura. *D. manskii* may possibly be a synonym or a subspecies of *recurrens*. Mr. May, in correspondence, stated that he did not consider the darker or lighter colorings to be of any value in this case since there is considerable variation depending upon the age (before killing) of the specimen. One specimen (from the type locality and host) received for study from Mr. May has the mesonotum extensively blackened and would fit the original description of *recurrens* very closely. It will be necessary to study specimens of *recurrens* from New Guinea in order to be sure that these are synonyms.

This species is distinguished from all other known Australian Dacinae by the conspicuous S-shaped band through the median part of the wing (see Perkins and May, 1949:4, fig. 1, and Hering, 1941*a*:47, fig. 2). *Wings:* The band extends transversely across the wing from vein R_{4+5} through the r–m crossvein to the wing margin just below the apex of vein M_{3+4}; it then extends dorsally along the m crossvein into cell R_5 nearly to vein R_{4+5}; then it curves downward again, extends along vein M_{1+2} and ends in the wing margin just below the apex of this vein. The first two costal cells are brownish-yellow-fumose and are densely covered with microtrichia except in the basal part of the first cell. The costal band is very broad, filling all of cell R_3. The cubital streak is broad, filling all of the basal part of cell M_4 up to the top margin of the m–cu crossvein. The narrowed portion of the cubital cell is slightly more than three times longer than the distance from the apex to the wing margin in the males and about two times longer in the females. *Thorax:* Chiefly reddish-yellow, typically with a pair of sublateral shining black stripes on the mesonotum just inside the postsutural yellow stripes. In the series at hand the coloration of the thorax varies considerably from specimens which are almost entirely reddish with brownish markings on the dorsum to those which have the

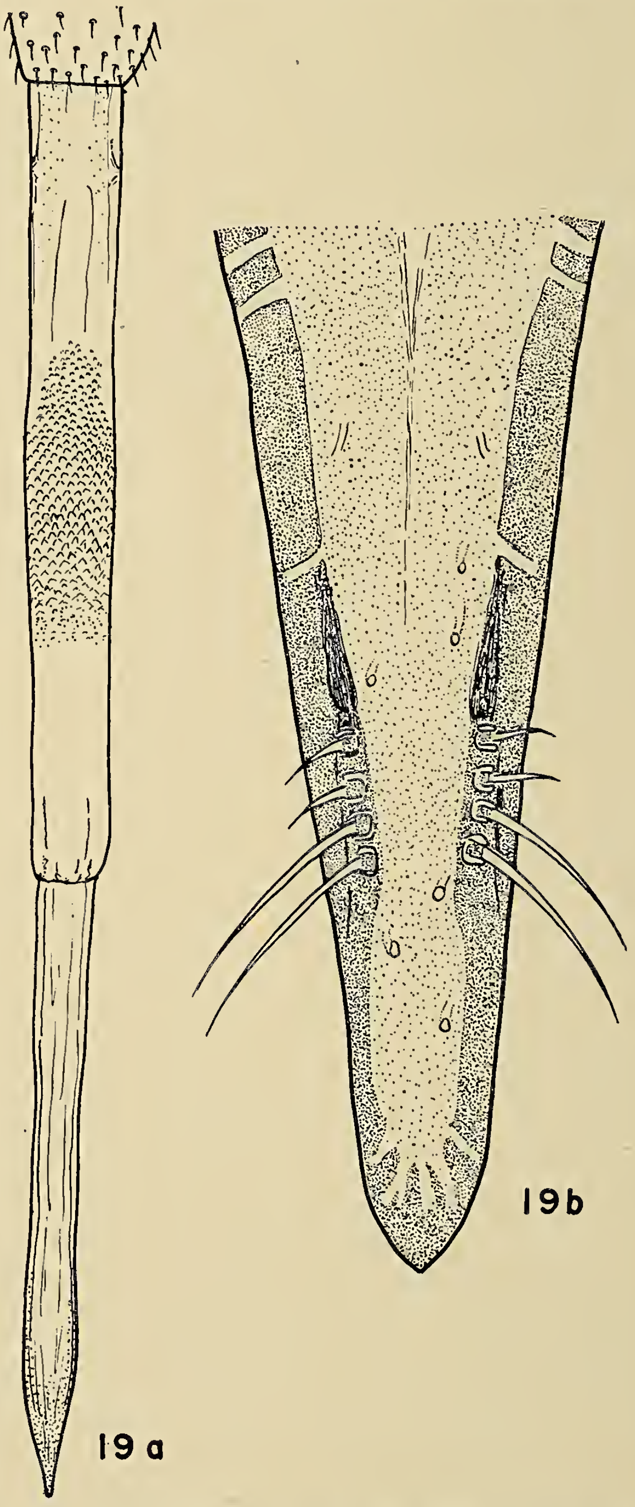

FIG. 19. *Dacus* (*Strumeta*) *manskii* (Perkins and May): a, ovipositor, full length; b, apex of ovipositor.

mesonotum chiefly blackish and grayish pollinose as in *recurrens. Abdomen:* First tergum brown on the basal three-fourths, black on the lateral margins. This black margin continues posteriorly and runs into the black band on the second tergum. Second and third terga with moderately broad black bands across their bases. The black crossband on the third expands laterally, covers all of the side margins, and extends posteriorly over the lateral margins of terga 4 and 5, narrowing rather sharply as it approaches the apex of the abdomen. A broad black vitta extends down the median part of the abdomen from the basal band on the third tergum to the apex of the fifth tergum. The fifth segment is all rufous except for the extreme lateral margins and the median vitta. *Ovipositor:* The exposed portion of the ovipositor is about equal in length to segments 4 and 5 combined. The extended ovipositor is long and slender (Fig. 19*a*) reaching a length of about 6.2 mm. The piercer (Fig. 19*b*) measures appoximately 1.8 mm. long by 0.2 mm. wide. The oviduct extends to within about 0.28 mm. of the apex, and the setae are situated about 0.05 mm. from the apex of the piercer. The distance from the distad pair of setae to the apex is equal to about two times the length of the plate bearing the setae or to the lengths of the longest setae. The inversion membrane is about 2.0 mm. long by 0.25 mm. at its widest point. The scales of the rasper extend to within about 0.9 mm. of the base of the eighth segment. The basal segment of the ovipositor measures about 1.4 mm. in length. The spiracles are situated approximately 0.3 mm. from the base of the segment.

Length: Body, 5.4–6.2 mm.; wings, 5.0–5.7 mm.

TYPE LOCALITY: Cairns, bred from *Strychnos bancroftiana.* No type designated.

Type series in the Queensland Museum.

Thirteen specimens are in the Krauss collection from: Babinda, Queensland, ex *Strychnos* sp., Nov., 1949, and Iron Range, Queensland, ex *Strychnos* sp.(?) prob. *bancroftiana*, Aug., 1949.

Dacus (Strumeta) mayi new name

Fig. 20*a*, *b*

Strumeta bilineata Perkins and May 1949. Univ. of Queensland, Dept. Biol. 2(14): 7–8. This name is preoccupied in *Dacus* by *D. bilineatus* Walker 1860. Linn. Soc. Lond., Proc. 4: 150.

No specimens were present in the Krauss collection, but specimens for study have been received from Mr. Alan May. A brief description and figures of the ovipositor are given here in order to compare this with the related species that are discussed.

D. mayi is related to *D. breviaculeus* and differs from it in the ways discussed under that species. The ovipositor is comparatively short

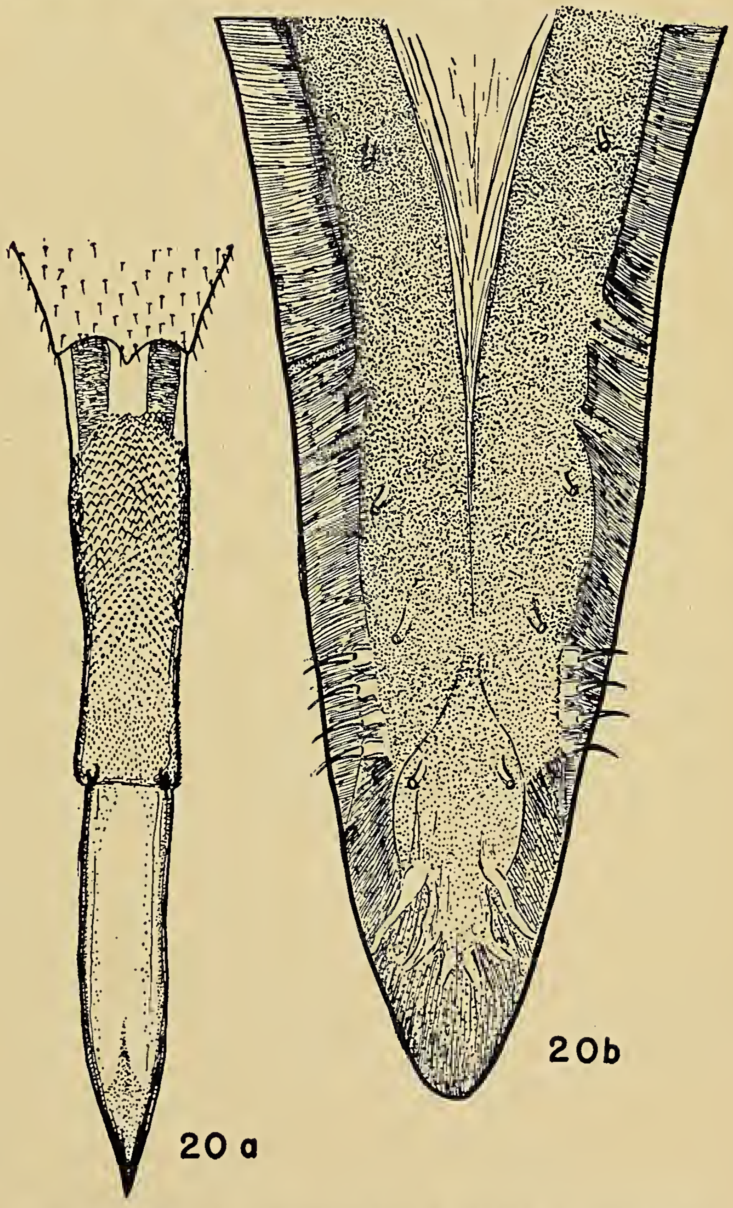

FIG. 20. *Dacus* (*Strumeta*) *mayi* n. name: a, ovipositor, full length; b, apex of ovipositor.

and thick; it is not broad, however, as in *breviaculeus* (cf. Figs. 12*b* and 20*a*). In undissected specimens the extended portion is equal to or slightly longer than segment 5 and not scarcely extended beyond segment 5 as in *breviaculeus*. The extended ovipositor (Fig. 20*a*) measures approximately 3.5 to 3.7 mm. The piercer is 1.1 to 1.2 mm. long by about 0.26 mm. at its widest point. The oviduct extends to within about 0.18 mm. from the apex of the piercer (Fig. 20*b*), and the setae are about 0.05 mm. from the apex; this latter distance is comparable to about two times the length of the plate bearing the setae. On each side of the base of the piercer a pair of sclerotized lobes extends a short way inside the apical portion of the inversion membrane (segment 8). The inversion membrane measures 1.2 to 1.4 mm. in length by about 0.38 mm. at its widest point (at the base). The scales are thorn-like and extend to within about 0.2 mm. of the base of the segment. The apical portion of the inversion membrane is densely covered with short hairs, especially visible on the sides. The basal segment of the ovipositor is about 1.2–1.3 mm. long by 1.1 mm. across its hind margin. The spiracles are located about 0.3 mm. from the posterior lateral margins of the segment.

TYPE LOCALITY: Cairns, Queensland, bred ex *Sideroxylon obovatum* (R. Br.).

Type in the University of Queensland collection.

Dacus (Strumeta) musae (Tryon)

Fig. 21*a–c*

Chaetodacus musae Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 197–199.

This species is related to *D. endiandriae* (Perkins and May). It is distinguished by the pale-colored abdomen which lacks the central black vitta and by the striking differences in the female ovipositors (Figs. 15*a* and 21*b*).

MALE. *Head:* All rufous, except for the black facial spots and ocellar triangle and for the brownish discoloration in the center of the front. The front is slightly expanded on the lower half and is one and three-fourths times longer than wide. Two pairs of inferior fronto-orbital bristles are present. The facial spots are oval and are situated about half their length from the oral margin. The third antennal segment is brownish, about one and one-fourth times longer than the face, and is slightly more than four times longer than wide. The head bristles are brown to black. *Thorax:* The dorsum is chiefly black, especially in the median portion. The area between the postsutural yellow stripes is grayish pubescent and is divided off by the usual three longitudinal subshining lines. The scutellum is all yellow except for a very narrow brown line across its base. The vertical yellow stripe through each mesopleuron is expanded dorsally and extends over all but a small portion of the top margin of the sclerite. The metanotum is black with a reddish central portion. *Legs:* Entirely rufous except for some brownish discoloration on the coxae and hind tibiae. *Wings:* The first two costal cells are hyaline and devoid of microtrichia except in the outer part of the second cell. The costal band is rather broad but does not extend to vein R_{4+5} except at its apex (Fig. 21*a*). The cubital streak is broad, fills all of the base of cell M_4, and extends about halfway along the m–cu crossvein. The narrowed portion of the cubital cell is three times longer than the distance from the apex to the wing margin. *Abdomen:* Almost all yellowish to rufous. The first tergum is brownish, especially on the sides, and the second tergum has a reddish-brown subbasal band. The third tergum usually has a narrow, black basal band, distinct especially at the sides. In some specimens this tergum is all pale, in others just a small anterior lateral spot of black is present on each side.

Length: Body, 7.0–7.3 mm.; wings, 6.0–6.2 mm.

FEMALE. The narrowed portion of the cubital cell is two times longer than the section to the margin beyond the apex. Some specimens have a very faint indication of a vitta

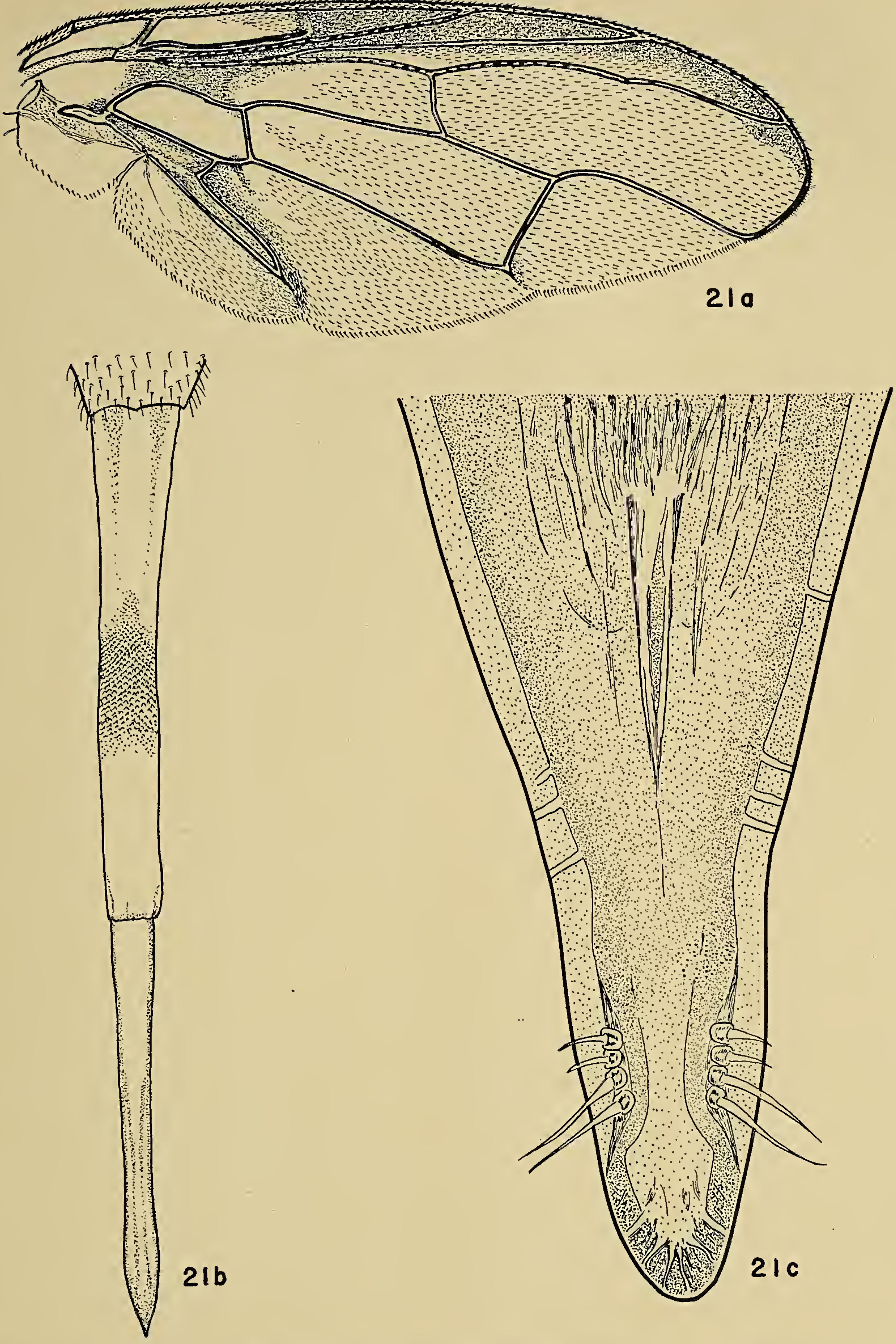

Fig. 21. *Dacus* (*Strumeta*) *musae* (Tryon): a, wing; b, ovipositor, full length; c, apex of ovipositor.

down the middle of terga 4 and 5. *Ovipositor:* Elongate and conspicuous, the visible portion equal to the combined lengths of terga 4 and 5. It is distinctive even in *in situ* specimens because of the position of the pre-apical setae. The extended ovipositor (Fig. 21*b*) measures about 5.4 mm. in length. The piercer is approximately 1.8 mm. long by 0.2 mm. wide. It tapers rather abruptly just beyond the apex of the oviduct. The oviduct extends to within 0.5 mm. of the tip of the piercer. The setae are conspicuous and are located just before the apex of the piercer. They are about 0.04 mm. from the apex, this distance being just slightly more than the length of the plate bearing the setae or the lengths of the longest setae (Fig. 21*c*). The inversion membrane is about 2.0 mm. long by 0.32 mm. wide. The scales of the rasper are sharp-pointed and extend to within approximately 0.9 mm. from the base of segment 8. The basal segment is 1.6 mm. long and the spiracles are 0.27 mm. from the posterior lateral margins.

TYPE LOCALITY: Cardwell, Queensland, ex *Musa banksii.*

Type in the Queensland Museum.

Over 1,000 specimens are in the Krauss collection from the following localities: Cairns, Queensland, ex banana, Jan.–Feb., 1950; Mossman Gorge, Queensland, ex *Musa banksii*, Feb., 1950; near Deeral, Queensland, ex banana, June, 1949; near Kuranda, Queensland, ex *Musa banksii*, Sept., 1949; Mossman, Queensland, ex *Musa banksii*, March, 1950; one specimen reared from guava, Cairns, Queensland, April, 1950; one specimen reared from *Capparis lucida*, Ellis Beach near Cairns, Jan., 1950; and two specimens from Cairns, ex papaya, Feb., 1950.

Dacus (Strumeta) pallidus

(Perkins and May)

Fig. 22*a*, *b*

Strumeta pallidus Perkins and May 1949. Univ. of Queensland, Dept. Biol. 2(14): 10–12.

A predominantly pale-colored species related to *D. barringtoniae* (Tryon). It is readily distinguished by the presence of a black vitta down the middle of abdominal terga 3 to 5 and by the very striking differences in the ovipositors as shown in Figures 11*a* and 22*a*.

The species has been adequately described by Perkins and May, except for the genital characters. The following description points out the diagnostic characters. *Head:* The front is broad; it is slightly less than the width of one eye and about one and three-fourths times longer than wide. There are two pairs of inferior fronto-orbital bristles. One specimen in the series at hand has three bristles on one side and two on the other. The facial spots are oval and are sometimes pointed below. In a series of specimens from Iron Range about 50 per cent had no facial spots; they were evidently teneral. *Thorax:* Chiefly reddish with the usual yellow markings, the sternopleura largely brown to black. There is also a small black spot behind the yellow coloration of the metapleura just in front of the halteres and a brown to blackish spot on some specimens on the hypopleura just above the hind coxae. In one specimen at hand a pair of dorsocentral bristles are distinctly developed; these are placed anterior in position to the prescutellars and are about half as long as the other thoracic bristles. *Wings:* The first two costal cells are hyaline and devoid of microtrichia except in the apical portion of the second. The costal band extends under vein R_3 through the dorsal half of cell R_3. In the apical portion it extends over one-third the distance between the ends of veins R_{4+5} and M_{1+2}. The cubital streak is more faintly yellow-brown than the costal band, and the yellowish coloring fades out at about the end of the cubital cell. In the female the narrowed portion of the cubital cell is equal to or slightly longer than the distance from the end of the cell to the wing margin. In the male this cell is distinctly more than two times longer than the distance to the margin. *Abdomen:* Chiefly reddish with a black vitta down the middle of terga 3 to 5 and a narrow brown to black basal band on the third tergum. This basal band broadens laterally and covers the side margins of this tergum. *Ovipositor:* Conspicuous and well developed. The extruded portion (in pinned specimens) is about equal in length to the last three segments of the abdomen. The extended ovipositor (Fig. 22*a*) measures about 5.4 mm. The piercer (Fig. 22*b*) is 1.8 mm. long by 0.19 wide and is gradually tapered on the apical third. The apex of the oviduct is about 0.6 mm. from the apex of the piercer. The setae are well developed and are situated about 0.25 mm. from the apex of the piercer.

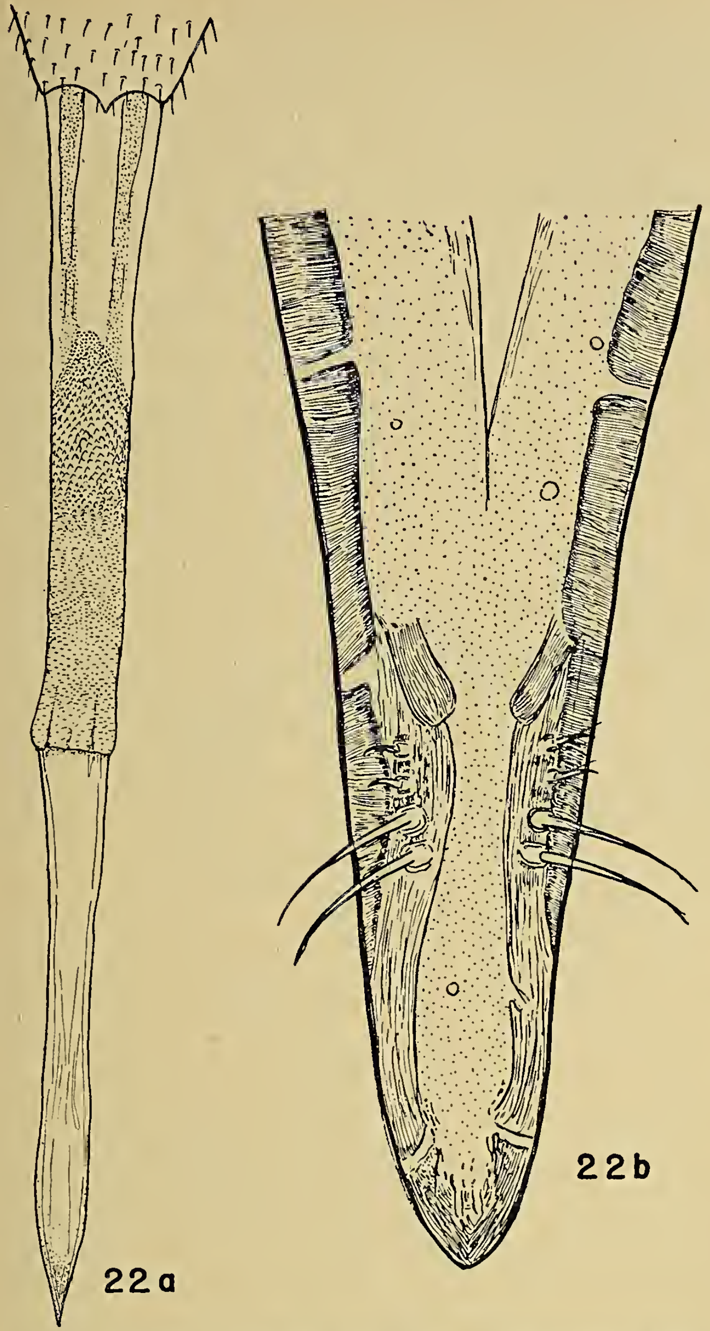

FIG. 22. *Dacus* (*Strumeta*) *pallidus* (Perkins and May): a, ovipositor, full length; b, apex of ovipositor.

This distance is equal to about twice the length of the longest pre-apical setae or two to three times longer than the plate bearing the setae. The inversion membrane measures about 2.1 mm. long by 0.3 mm. wide. The scales of the rasper extend to within about 0.75 mm. of the base of the segment. The basal segment is about 1.5 mm. long by 1.1 mm. at its broadest point. The spiracles are 0.14 mm. from the base of the segment, measured on the lateral margin.

Length: Body, 6.4–6.6 mm.; wings, 5.8–6.0 mm.

TYPE: No type or type locality was designated. It was described from a series bred from fruits of *Sarcocephalus cordatus* Miq. collected at Cairns and Brisbane, Australia. Type series in the University of Queensland collection.

The Krauss collection contained a large series of this species from Cairns, Queensland, ex *Sarcocephalus cordatus*, Mar.–Apr., 1950, and 20 specimens from Iron Range, Queensland, ex "undet. yellow fruit," Aug., 1949.

Dacus (Strumeta) pulcher (Tryon)

Fig. 23*a*, *b*

Bactrocera pulcher Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 206–207.

This species superficially resembles *Dacus* (*Heterodaculus*) *visendus* n. sp. because of the similarity in the wing markings. The two species are not related, however, and could not be confused. The species appears to be related to *D. strigatus* (Perkins) but is readily separated by the brown costal cells, the yellow notopleural calli, and the more anteriorly placed r–m crossvein.

MALE. Chiefly black or dark colored species. *Head:* Rufous, except for the blackened occiput, the black facial spots, and the discolorations on the front. The front is about one and one-half times longer than its greatest width. The front is gradually expanded on the lower half, and the median tumescence is discolored with brown. Two pairs of inferior fronto-orbital bristles are present on the specimen at hand. In the original description Tryon stated that three pairs of inferior frontals were present. All of the head bristles are black. The facial spots are elongate, are equal to half the length of the face, and extend to the oral margin. The first two antennal segments are rufous, tinged lightly with brown. The second segment is comparatively long, being one and one-half times longer than the first segment and nearly half as long as the third. The third segment is brown in color, is almost one and two-fifths longer than the face, and is nearly five times longer than wide (Fig. 23*a*). *Thorax:* Dorsum black except for the humeri, notopleural calli, lateral yellow postsutural vittae, and the scutellum. The median portion

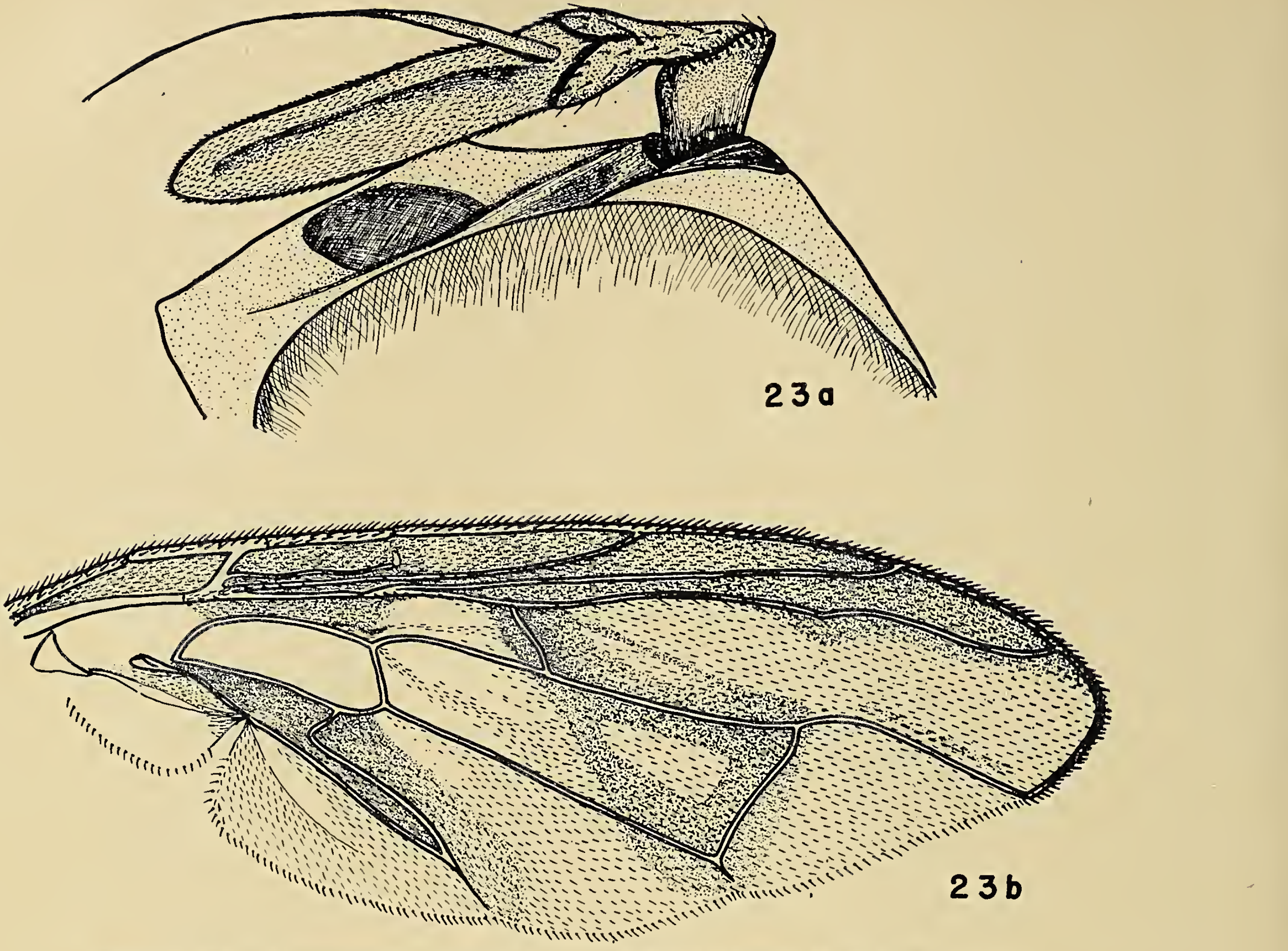

FIG. 23. *Dacus* (*Strumeta*) *pulcher* (Tryon): a, head, lateral; b, wing of male.

is densely covered with grayish pubescence which is very indistinctly divided by three narrow, subshining longitudinal vittae. The lateral yellow stripes are narrow, extend from the suture to the inner supra-alar bristles, and are slightly discolored with brownish on the posterior half. The yellow coloring extends a short distance along the suture on each side. The scutellum has a broad black band across its base. The scutellar bristles are about as widely spaced as the prescutellars. The yellow mesopleural stripe is almost parallel sided, just gradually expanding toward the top margin. The anterior half of each mesopleuron is shining black. *Legs:* Coxae black, trochanters discolored with brown, legs otherwise yellowish-red. *Wings:* Costal band and cubital streak very broad and dark brown-fumose. The first two costal cells are concolorous with the remainder of the costal band and very densely and completely covered with microtrichia. The costal band fills all of cell R_3 and extends a short distance below vein R_{4+5} on the outer half of that vein. The cubital streak fills all of the basal part of cell M_4 almost to the top margin of the m–cu crossvein and extends in a broad, almost parallel-sided band to the wing margin. A broad crossband extends obliquely through the middle of the wing. This runs from vein R_{4+5} at the r–m crossvein to the wing margin at the apex of vein M_{3+4}. This takes in the r–m and m crossveins and fills all of the apical half of cell 1st M_2 except for a triangular-shaped hyaline spot in the center of this portion (Fig. 23*b*). The r–m crossvein is straight but oblique in position; it is situated anteriorly to the middle of cell 1st M_2 and well before the apex of vein R_{1+2}. In the male the narrowed portion of the cubital cell is two times longer than the portion from the apex of the cell to the wing margin. *Abdomen:* Almost all black, the apical half of the second tergum whitish to yellowish, and the apical half of the fifth tergum rufous, discolored with brown to black on the anterior portion of this band. The integument is densely covered with minute punctules.

Apparently the female has not been described, and no specimens have been seen during this study.

Length: Body, 7.0 mm.; wings, 6.0 mm.

TYPE LOCALITY: Glasshouse Mountain, South Queensland.

Type in the Queensland Museum. One male specimen is in the Krauss collection from Atherton Tableland, Queensland, ex *Planchonella* sp., Sept., 1949.

Dacus (Strumeta) tryoni (Froggatt)

Fig. 24*a*, *b*

Tephritis tryoni Froggatt 1897. Agr. Gaz. N. S. Wales 8: 410–412, fig. 18.

Chaetodacus tryoni var. *musa* Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 187.

Chaetodacus tryoni var. *juglandis* Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 188.

Apparently this species is quite variable in color and it is questionable that the designation of color varieties has any value in this case. In some series of *D. tryoni* I have found that a high percentage will often fit the variety *sarcocephali* and in some cases the individuals intergrade into a more melanistic form which appears to be typical *melas* (Perkins and May). The variety which Tryon described as *musa* appears to be the same as typical *tryoni*, and his variety *juglandis* is evidently an intergrading form between typical *tryoni* and variety *sarcocephali*.

Dacus tryoni has been treated frequently in the Australian literature and for the most part the taxonomic details have been adequately covered. The following discussion gives the most important characteristics of the species. The species is well defined by the yellow-brown-fumose costal cells which are densely covered with microtrichia. The female ovipositor is also distinctive and is very useful in separating this species. The typical form has the thorax chiefly rufous without longitudinal black vittae or black markings on the mesonotum.

Head: The facial spots are circular to oval and are often somewhat pointed on the lower margin. The shape of the spots does not appear to be of importance in distinguishing this species or in setting off varieties. *Thorax:* The ground color of the median portion of the mesonotum is yellowish (well differentiated from the cream-colored lateral vittae etc.), bounded on each side by reddish to reddish-brown. Specimens often have a pair of short brown to black stripes arising from between the outer and inner scapular bristles and extending about the length of the humerus from the anterior margin of the mesonotum. When these black marks extend the full length of the mesonotum, the specimen fits in the *sarcocephali* group. The humeri are clear yellow to cream colored. In some specimens they are discolored with brownish and definitely intergrade into the *humeralis* form. *Wings:* The most striking characteristic is the presence of microtrichia throughout the apical portion of the first costal cell and through all of the second. These two sections are usually brownish-fumose, concolorous with the costal band. In teneral specimens the brownish coloring may be absent, but the presence of the microtrichia (best seen at magnifications of 90 to 112×) will differentiate the species. The costal band is distinct but extends only faintly below vein R_3 except at the wing margin. The cubital streak is broad and well developed. It fills all of the basal portion of cell M_4. The narrowed portion of the cubital cell is about one and one-third times longer than vein Cu_1+1st A in the females, and in the males the narrowed portion of the cell is slightly over two times longer than Cu_1+1st A. *Abdomen:* Variable in coloration, typically the third tergum is all brownish to black, the fourth is brown to black on the sides, and the fifth is brown on the posterior lateral margins. A dark-colored vitta extends down the middle of terga 3 to 5. Tergum 2 has a brown to black subbasal band and the basal three-fourths of the first segment is brown. In the specimens at hand the coloring of the abdomen varies from nearly all rufous to nearly all shining black. *Ovi-*

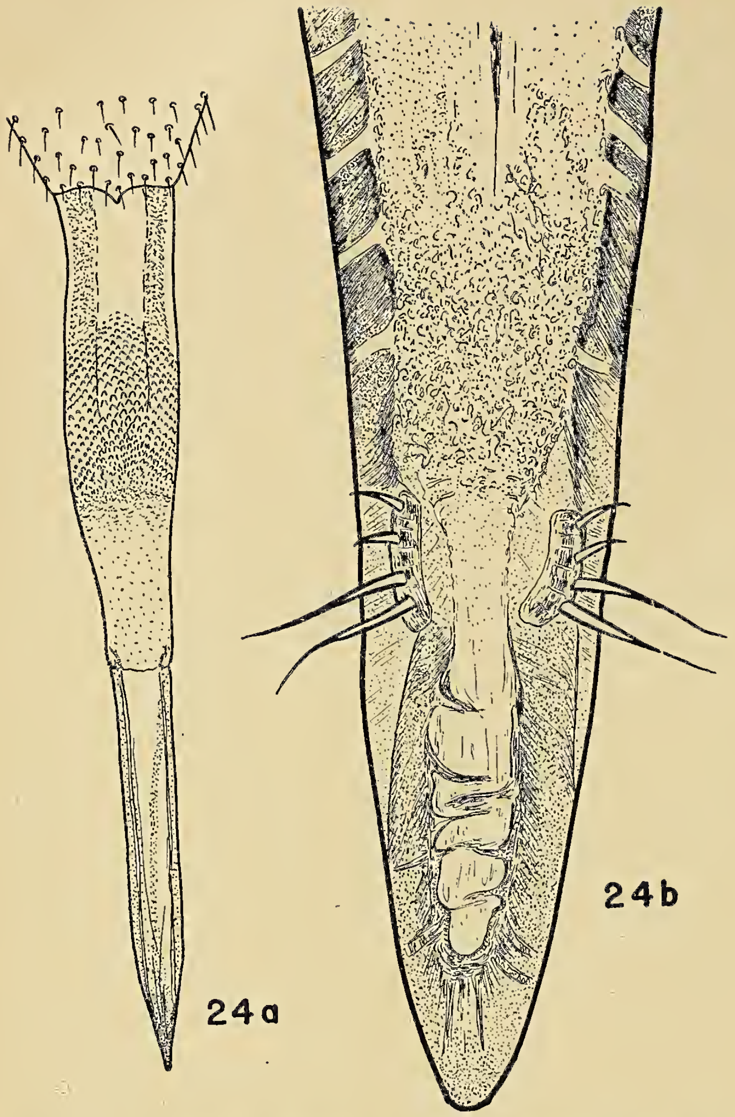

Fig. 24. *Dacus* (*Strumeta*) *tryoni* (Froggatt): a, ovipositor, full length; b, apex of ovipositor.

positor: Moderately short in *in situ* specimens; the visible portion is about one and one-half times longer than the fifth tergum. The extended ovipositor (Fig. 24*a*) is about 4.0 mm. long. The piercer measures about 1.27 mm. long by 0.19 mm. at its widest point. The setae are located about 0.09 mm. from the apex of the piercer (Fig. 24*b*), this distance being comparable to about four times the length of the plate bearing the setae or four times the length of the longest setae. The apex of the oviduct is about 0.26 mm. from the tip of the piercer. The inversion membrane is about 1.5 mm. long by 0.3 mm. wide at its base. The scales of the rasper are broad and rather blunt and extend to within 0.45 mm. from the base of the segment. The basal segment is about 1.2 mm. long by 1.07 mm. across its hind margin. The spiracles are located about 0.28 mm. from the posterior lateral margin of the segment.

Length: Body, 6.0–7.0 mm.; wings, 5.0–6.0 mm.

TYPE LOCALITY: Tenterfield, New South Wales.

Type in the Queensland Museum.

Several thousand specimens are in the Krauss collection from the following localities and hosts: Palm Beach, near Cairns, Queensland, ex *Terminalia melanocarpa*, *T. muelleri*, and *Mimusops parvifolia*, Dec., 1949; near Gordonvale, Queensland, ex *Solanum seaforthianum*, Aug.–Dec., 1949; Garradunga, Queensland, ex *Eugenia suborbicularis*, Aug., 1949; Hartley's Creek, Queensland, ex *Polyalthia nitidissima*, Mar., 1950; near Atherton, Queensland, ex *Castanospora alphandii*, Dec., 1949; Julatten, Queensland, ex *Castanospora alphandii* and *Amorphospermum antilogum*, Dec., 1949; near Babinda, Queensland, ex guava; Atherton Tableland, Queensland, ex *Planchonella* sp., *Endiandra compressa*, *Solanum auriculatum*, *Rhipogonum papuanum*, *Aglaia sapindina*, and *Beilschmiedia obtusifolia*, Nov., 1949–Feb., 1950; Babinda, Queensland, ex *Endiandra compressa*, Nov., 1949; Mowbray River, Queensland, ex *Capparis lucida*, Feb., 1950; Ellis Beach, near Cairns, Queensland, ex *Terminalia catappa*, Feb., 1950, and ex *Dallachya vitiensis*, Jan., 1950; Ravenshoe, Queensland, ex peach and plum fruit, Dec., 1949; Gosford, New South Wales, ex *Actinidia chinensis* and "Feijoa," Apr., 1950; and Sydney, New South Wales, ex *Psidium cattleianum* var., *Eugenia pendula*(?), and *Hemicycla australiensis*, Apr., 1950.

Also reared from the following hosts at Cairns, June, 1949, to Mar., 1950: ex *Eugenia cormiflora*, *Eugenia jambos*, *Psidium guajava*, papaya, mango, *Annona reticulata*, *Terminalia muelleri*, *Terminalia catappa*, cashew, *Carambola*, *Castanospora alphandii*, and ex "reddish purple fruit ½ m. [inch?] diam."

Dacus tryoni var. **melas**
(Perkins and May) new combination

Strumeta melas Perkins and May 1949. Univ. of Queensland, Dept. Biol. 2(14): 12–14.

I have not been able to find characters on the specimens available which will separate this as a distinct species. It apparently intergrades with var. *sarcocephali*, and in several series at hand it is impossible to place specimens which occupy a borderline position between the two forms. This is apparently just a melanistic form of *D. tryoni*. The female ovipositor and other structural characteristics of the specimens which have been studied are identical with typical *tryoni*. According to the original description, *Strumeta melas* Perkins and May is very close to *tryoni* var. *sarcocephali* "from which it differs in the shape of the facial spots and the colour of the mesonotum and abdomen. Though closely resembling *S. humeralis* in general colouration it differs in the colour of the humeral calli."

Specimens of *Strumeta melas* from the type locality have been sent to me for study by Mr. Alan May. In this series, as well as in other series at hand, the facial spots, from circular to pointed below, show the same variations in shape as in the typical form. They are definitely blacker than in var. *sarcocephali* but structurally do not seem to differ from typical *tryoni*. The range in size is also the same as in the typical form in the specimens at hand. The ovipositors appear to be identical.

TYPE LOCALITY: Not designated in original description. Described from "four specimens 'bred' from grapefruit in Gayndah, Nambour and Palmwoods."

Type series in the University of Queensland collection.

Typical *melas* are in the collection from many localities. In most cases they are mixed with series of typical *tryoni* and var. *sarcocephali*. Specimens are from Cairns, Queensland, "resting on guava fruit," Feb., 1950; Atherton Tableland, Queensland, ex *Eugenia* sp. (*luenmannii?*), Nov., 1949. Specimens are also mixed in with several of the series of typical *tryoni* reported above.

Dacus tryoni var. **neohumeralis**
new name

Chaetodacus humeralis Perkins 1934. Roy. Soc. Queensland, Proc. 45(9): 42–43. This name is preoccupied in *Dacus* by *D. humeralis* Bezzi 1915. Ent. Res. Bul. 6: 95.

I am quite skeptical about this form (or species?). Numerous specimens are on hand which fit the description of *Strumeta humeralis* Perkins, but they appear to be just specimens of *D. tryoni* with discolored humeri. The general body color in the series at hand varies from predominantly pale, as in typical *D. tryoni*, to chiefly black, as in *D. tryoni* var. *melas*. Specimens in the present collection compare exactly with specimens which had been determined as *D. humeralis* by Perkins. The ovipositor and other structural characteristics are identical with those of *tryoni*. Mr. Alan May feels that this is a distinct species. He has stated (in correspondence) that "*humeralis* Perkins can be separated quite readily from *tryoni*, particularly when you are handling either field specimens or fully coloured material. Young flies of *tryoni* do discolour and the humeral calli may change to brown as the pinned specimens age. However, *humeralis* has an extensive black pattern on the mesonotum while the humeral calli are also black." The specimens which Mr. May sent to emphasize his point showed the same variations in the color of the humeri present in the series at hand—from dirty yellow to brownish (not black). This may be entirely due to the age (before killing) of the specimens, but since I have not been able to find supporting structural differences I prefer to treat this as a variety of *tryoni*.

TYPE LOCALITY: Mackay, Queensland, ex *Passiflora suberosa*.

Type in the Queensland Museum.

Specimens are in the Krauss collection from the following localities and hosts: Ellis Beach, near Cairns, ex *Granophyllum falcatum*, Jan.; 1950, and ex *Capparis lucida*, Jan., 1950;

Cairns, same host and date as above, mango, Dec., 1949, and guava, Apr., 1950; across inlet from Cairns, ex "fruit plant No. 138,"[6] Feb., 1950; and near Hartley's Creek, N. Queensland, ex *Clausena brevistylus*, Feb., 1950. NOTE: In the longer series of specimens from the above localities and hosts the humeri vary in color from brown to yellow.

Dacus tryoni var. **sarcocephali** (Tryon)

Chaetodacus tryoni var. *sarcocephali* Tryon 1927. Roy. Soc. Queensland, Proc. 38(14): 188.

As discussed above, this is just a color variation of *D. tryoni*, and in many of the series at hand so many borderline specimens are present (also verging into var. *melas*) that it does not seem practical to break them down even into varieties. Since variety *sarcocephali* apparently is commonly accepted by the Australian workers, I am including it in this discussion. The variety is supposed to differ from typical *tryoni* by having distinct black markings on the mesonotum, according to Perkins and May, "comprising two dots and two streaks." They also say that the flies are mostly smaller in size. The size difference apparently is of no importance as no constant difference in size has been observed in the long series at hand. The ovipositors are identical with the typical form. Mr. May offered the following comments in one of his letters, "Re Tryon's 1927 paper and the varieties of *S. tryoni:* I have yet to go into this problem. . . . Should you regard var. *musa* and var. *juglandis* as true synonyms, then you would also treat var. *sarcocephali* on the same basis? I have yet to find differences of a structural nature, between *tryoni* and *tryoni* var. *sarcocephali*. Var. *juglandis* is quite a small fly in comparison to *tryoni* but that could be due to food." I may not be correct in treating the forms in this *tryoni* complex as I have, but the procedure followed here seems to be the most logical way of handling them.

TYPE LOCALITY: Brisbane, ex *Sarcocephalus cordatus* and *Psidium* sp.

Type in the Queensland Museum.

Typical *sarcocephali* are in the collection from Hartley's Creek, N. Queensland, ex *Polyalthia nitidissima* and *Ganophyllum falcatum*, Feb.–Mar., 1950 (some of these intergrade into var. *melas*); Atherton Tableland, Queensland, ex *Rhodamnia sessiliflora* and *Solanum seaforthianum*, Mar., 1950; Cairns, Queensland, ex guava, Mar., 1950 (intergrading into var. *melas*); near Hartley's Creek, N. Queensland, ex *Terminalia melanocarpa*, Mar., 1950 (smaller specimens intergrading in color toward var. *melas*); Ellis Beach near Cairns, Queensland, ex "plant 129,"[7] Feb., 1950; also mixed in with a large share of the typical *tryoni* reported above.

ACANTHONEURA Macquart

Acanthoneura Macquart 1843. Dipt. Exot. 3(3): 220.

This genus is closely related to *Rioxa* Walker but the aristae are short haired and just one pair of inferior fronto-orbital bristles is present. According to Malloch (1939) three species of *Acanthoneura* occur in Australia. Just one species, *A. australina* Hendel, was represented in the Krauss collection. It now appears that a fourth species, *A. bicolor* (Mq.), should be included here.

GENOTYPE: *Acanthoneura fuscipennis* Macquart.

KEY TO KNOWN AUSTRALIAN *Acanthoneura*[8]

1. Abdomen entirely black; thorax yellow-brown without black markings; wings with just one hyaline incision on the costa just beyond end of vein R_{1+2} and with two hyaline spots in

---

[6] Mr. Krauss reported that this plant was determined (from fruit only) as *Terminalia melanocarpa*, but he was doubtful of this determination. He stated that it came from a "large tree . . . dark purple fruit, ½ inch diameter, ¾ inch long, juicy purple pulp."

[7] The plant "was apparently lost en route to Mr. C. J. White, Government Botanist, Brisbane." Mr. Krauss said it came from a "small tree . . . small red fruit, 5⁄16 in. long, ¼ in. diameter, in large clusters."

[8] Adapted from Malloch (1939*a*).

cell R_5............*nigriventris* Malloch

Abdomen marked with yellow or rufous; mesonotum distinctly marked with black; if just a single hyaline incision is present on the costal margin, cell R_5 has three hyaline spots..... 2

2. With two hyaline incisions beyond vein R_{1+2}; r–m crossvein situated at about the middle of cell 1st M_2.... ....*australina* Hendel

Just one hyaline incision on the costal margin; r–m crossvein situated at the apical two-thirds to three-fourths of cell 1st M_2...................... 3

3. Mesonotum marked with black on the sides and the hind margin; cell R_5 with two hyaline spots beyond the r–m crossvein......*acidomorpha* Hendel

Mesonotum with four black longitudinal vittae; cell R_5 with one spot beyond the r–m.....*bicolor* (Macquart)

Acanthoneura australina Hendel

Fig. 25

Acanthoneura australina Hendel 1928. Ent. Mitteil. 17: 359.

This species is separated from the related species by the characters given in the above key. The pattern of the wing coloring is especially characteristic. The following notes are based upon the female; the male has apparently not been described.

Head: The front is rufous and is one and one-third times longer than wide; the width is almost equal to the eye width. The face is flat on the upper three-fourths and tumescent below. The antennae are broken off in the specimen at hand. *Thorax:* Yellow on the sides, scutellum, and the greater portion of the dorsum; the lateral and posterior margins of the mesonotum are black. The mesonotum is subshining lightly pollinose. The metanotum is chiefly black, faintly rufous in the middle. The dorsocentral bristles are placed distinctly behind the anterior supra-alars. The halteres are yellow. *Legs:* Entirely clear yellow. *Wings:* (Fig. 25.) The basal portion is chiefly brown. The first costal cell is brownish in the basal half to three-fourths and hyaline at the apex (to the h crossvein). The second costal cell is largely hyaline but is brown at its apex and base; the hyaline mark in the second costal cell extends across the wing as a wedge-shaped mark through cells R_2 and R and connects, rather indistinctly, with the narrow hyaline streak in the base of cell M_4, which bisects the r–m crossvein. The basal one-third of the subcostal cell is hyaline and the apical portion is brown. A wedge-shaped hyaline incision runs through the middle portion of cell R_2 (where vein R_{1+2} enters costa) and extends through three-fourths of cell R_3. A second hyaline incision is situated just beyond the first, extending just to vein R_3. Cell R_5 has an oval hyaline mark just above the m crossvein and another before the r–m crossvein. Cell 1st M_2 has a round hyaline spot in the middle near its apex and 2d M_2 has a hyaline streak extending obliquely from the wing margin three-fourths the distance through the middle

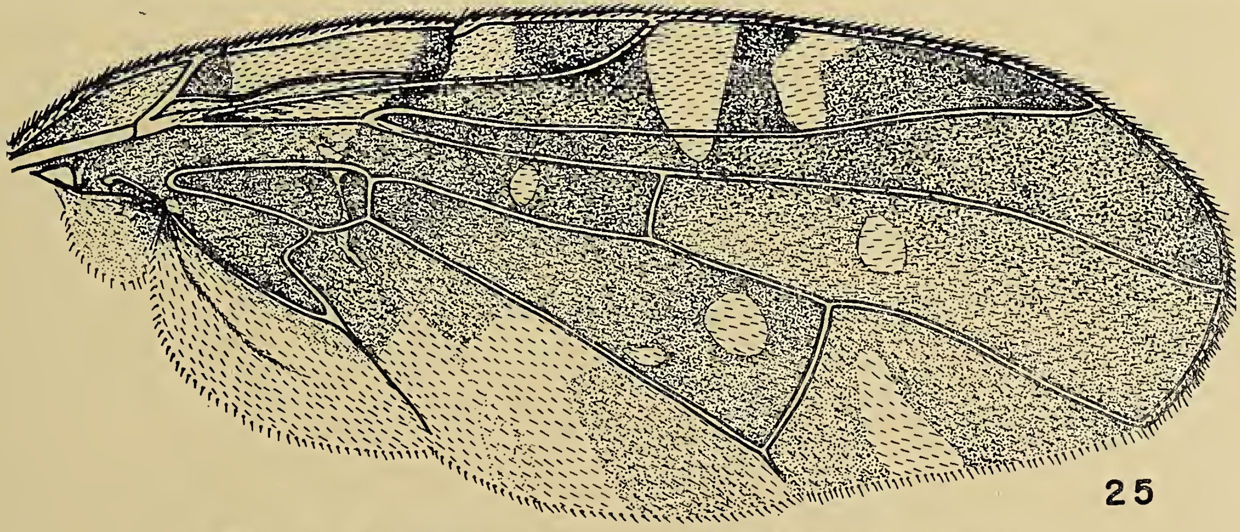

FIG. 25. *Acanthoneura australina* Hendel: wing of female.

of the cell. The brown coloring is rather faint in cell M_4 and indistinctly separates off three hyaline areas extending from the wing margin through the cell. The anal cell is hyaline except for a fumosity just below the anal vein. The squamae and fringe are largely black. *Abdomen:* First tergum yellow. Terga 2 to 4 are yellow to rufous in the middle, black on the sides. Fifth tergum all black, just faintly rufous in the middle. *Ovipositor:* Rufous and very conspicuous. The exposed portion is approximately two times longer than the remainder of the abdomen. The details of the piercer and inversion membrane have not been studied.

Length: Body, 5.0 mm.; wings, 6.0 mm.

TYPE LOCALITY: Cairns, North Queensland.

Type in the Deutsches Entomologisches Museum.

One specimen was in the Krauss collection from near Babinda, Queensland, Dec. 2, 1949.

Acanthoneura bicolor
(Macquart) new combination

Urophora bicolor Macquart 1855. Dipt. Exot., Suppl. 5: 144, pl. 7, fig. 7.

Rioxa bicolor Hendel 1928. Ent. Mitteil. 17(5): 352.

Rioxa bicolor Malloch 1939. Linn. Soc. N.S.Wales, Proc. 44(3–4): 436.

This species was not represented in the Krauss collection but its status was clarified during the course of this study and the information should be of value here.

The species described here as *Rioxa confusa* n. sp. was thought to be the same as *bicolor* (Macquart) and specimens were sent to Mr. J. E. Collin, Newmarket, England, for comparison with Macquart's type. Mr. Collin provided the following information in correspondence:

> In reply to your enquiry I give you below some details of the specimens standing under the name of *Urophora bicolor* in Bigot's collection. The one which appears to be the actual type (bearing a label in Macquart's handwriting) is not in very good condition, having the appearance of being originally preserved in spirit, and though described as a female, is actually, I am practically certain, a male with some extraneous matter stuck on to the end of the abdomen. With this type there are two other males apparently added later, which are certainly the same species, and were labeled by Macquart "*Urophora bicolor* Macq. Male, Australia."
>
> All these specimens are somewhat like those you sent me in wing markings, but entirely different in other characters, as noted below:—Arista practically bare. Face with an obvious median "keel" complete from lunule to mouthedge, quite narrow between antennae but rapidly widening out, leaving quite deep antennal foveae on each side. Frons wider than in your species, having two pairs of reclinate upper orbital bristles (front pair the longer) and only one pair of incurved lower orbitals, also numerous setulae scattered all over frons. Thorax tawny-yellow with four blackish stripes, middle pair wider than outer pair, and wider apart than they are from the outer ones. Scutellum tawny-yellow on a middle stripe but otherwise shining blackish except at extreme basal corner. Six equally strong scutellar bristles. A pair of prescutellar acrosticals and dorsocentrals, all equally strong, the latter placed slightly more anteriorly, and behind each of them (close to scutellar suture) a transverse row of about three much smaller bristles, a humeral, two notopleural, two supra-alar, and one postalar bristle, apparently no posthumeral or presutural. Pleurae yellow except metanotum which is blackish, bristles and all hairs black except latter on prothoracic episterna. Abdomen blackish at least towards tip, but sternites, and hypopygium beneath, of the same tawny-yellow colour as thorax. On wings the hyaline patches on each side of outer crossvein are slightly more widely separated than in Macquart's figures, and that on basal side of crossvein may be divided into two spots. Anal vein bent as in your species, but lower point of anal cell even longer. Insect larger and rather stouter than in your species, about 7 mm.

From these data it appears that Macquart's species belongs in the genus *Acanthoneura.*

It is distinguished from the other Australian species by the characters given in the above key.

TYPE LOCALITY: "Nouvelle-Hollande, Adelaide."

Type in J. E. Collin's collection (the Bigot collection), Newmarket, England.

Froggatt (1907) recorded the species from near Bathurst, New South Wales, "on trunks of wattle trees."

Bezzi (1913), Tryon (1927), Hendel (1928), and Malloch (1939*a*) have listed it as an Australian species. Malloch apparently erred when he stated: "the given type locality, Tasmania, is undoubtedly erroneous as usual."

CALLISTOMYIA Bezzi

Callistomyia Bezzi 1913. Ind. Mus. Mem. 3: 124.

This genus is distinguished from other Trypetinae which have four scutellar bristles by the short, stout, closely spaced spines on the ventral surface of the apical halves of the middle and hind femora. The known species are easily recognized as *Callistomyia* by the presence of a very large spot in the apex of the wing. This completely fills all of the apical three-fourths of cell R_5 and a large part of cell M_2. The wings are also characterized by a transverse band through the middle of the wing extending from the costal margin to the hind margin through the r–m crossvein. The chaetotaxy of this genus has been discussed by Malloch (1939*b*: 447).

GENOTYPE: *Callistomyia pavonina* Bezzi.

KEY TO KNOWN SPECIES OF *Callistomyia*

1. Abdomen with black bands on the anterior margins of terga 2 to, and including, 4 in the males and 5 in the females........................ 2
   Abdomen not banded, except on the base of tergum 2 in one species.... 3
2. The large apical spot in the wing is joined with the transverse band across the middle of the wing in the lower part of cell 1st M_2 (Philippine Islands).........*icarus* (Osten Sacken)
   The apical spot is isolated, not joined to the transverse band (India–Formosa).............*pavonina* Bezzi
3. The apical spot is joined with the transverse band (Australia)....*horni* Hendel
   Apical spot isolated (E. Indies)...... ....*klugi* (Wiedemann)

Callistomyia horni Hendel

Fig. 26

Callistomyia horni Hendel 1928. Ent. Mitteil. 17: 361.

This is the only species of the genus which has been recorded from Australia. It is separated by the characters brought out in the key. According to the original description the abdomen is entirely rust-red and the mesonotum has five longitudinal black vittae. The specimen at hand appears to fit the original description except that the second abdominal tergum has a broad, black band on its anterior margin and the mesonotum has just three dark vittae.

The species at hand may be new, but since just a single specimen is present I prefer to treat it as *horni* with a query. The following description is based upon this specimen.

MALE. Chiefly reddish. *Head:* Brownish-red in ground color, occiput yellowish. Front slightly expanded below the middle and two times longer than wide. The front possesses two pairs of inferior fronto-orbital bristles and two pairs of superior fronto-orbitals. The middle portion of the face is flat and nearly straight from the lateral view. The antennae are yellow, and the third segment is not much over half as long as the face and slightly over two times longer than wide. The longest hairs on the aristae are about equal to one-third the width of the third segment. *Thorax:* The chaetotaxy fits the generic arrangement given by Malloch (1939 *b*: 447) except that no humeral bristles are in evidence on the specimen at hand. The mesonotum is reddish with three narrow black vittae extending the full length—one down the middle and the other two in line with the dorsocentral bristles. The dorsal third to fourth of the pleura from the wing bases to the humeri are yellow, and the remainder is discolored with brown. The scutellum is all yellow except for a narrow brown band across the base. The metanotum is black, tinged with reddish in the middle. The halteres are reddish, tinged with brown. *Legs:* Chiefly yellow, tibiae tinged with brown. The middle and hind femora have two rows of short black bristles on the apical halves of the ventral surfaces. The hind tibiae have a row of short black bristles extending the entire length of the segment on the outer dorsal surface. The hind femora have a group of about 10 moderately strong black bristles arranged irregularly on the dorsal side near the apex. *Wings:* The large apical spot is joined with the transverse band across the middle of the wing in the lower portion of cell 1st M_2 (Fig. 26). The apical spot occupies all of the distal portions of cells R_5 and M_2 except for a narrow hyaline mark extending along the wing margin just above the apex of vein M_{3+4}. The last section of vein M_{3+4} from the m crossvein to the margin is comparatively elongate; it is equal to or longer than the r–m crossvein. *Abdomen:* Chiefly rufous except for a broad black band at the base of the first tergum and for the narrow black lateral margins of terga 1 to 5. The venter is entirely yellow to rufous.

Length: Body, 7.0 mm.; wings, 6.0 mm. Female unknown.

TYPE LOCALITY: Palmerston, West Australia.

Type in the Deutsches Entomologisches Institut.

The specimen at hand is from near Hartley's Creek, N. Queensland, ex *Clausena brevistylus*, Feb., 1950.

Mr. May has informed me, in correspondence, that one specimen of *Callistomyia horni* is in Mr. Perkins' collection from Cairns.

CLUSIOSOMA Malloch

Clusiosoma Malloch 1926. Linn. Soc. N. S. Wales, Proc. 51: 547.

This genus is related to *Themarohystrix* Hendel and is distinguished by the more elongated antennae, by the absence of the pteropleural bristle and the presence of strong bristles on the middle and hind tibiae, by having the anterior two pairs of orbital bristles proclinate and incurved, as well as by other chaetotaxic characters reported by Malloch (1939*b*: 423).

GENOTYPE: *Clusiosoma semifusca* Malloch.

The two known Australian species are separated as follows:

Facial spots present; mesonotum with a pair of submedian black vittae extending the entire length from the outer scapular bristles to the hind margin and continuing over the

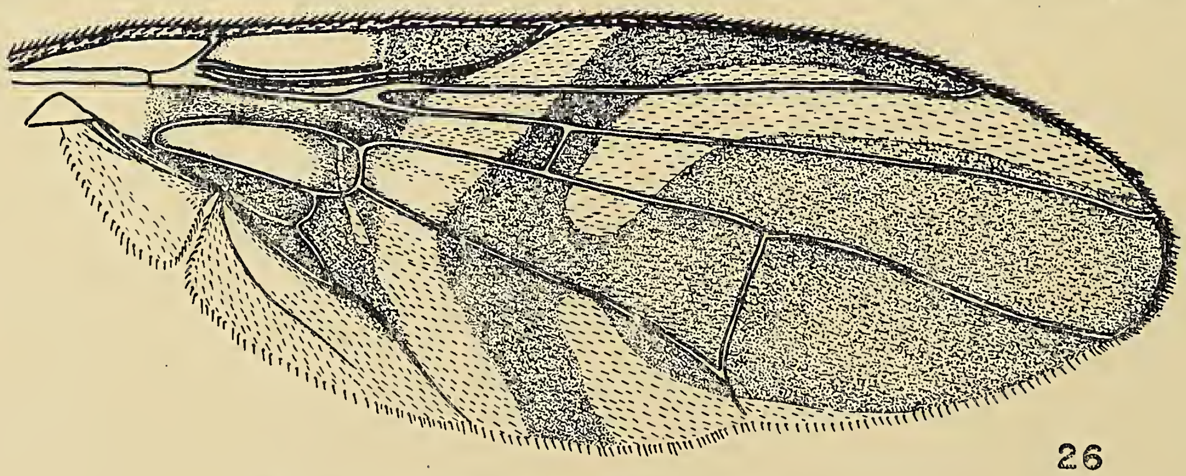

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FIG. 26. *Callistomyia horni* Hendel: wing of male.

scutellum; median portion of scutellum yellow; front metatarsus of male with a projection at the apex which is covered with minute black spines at its tip (Fig. 27*a*). . *puncticeps* Malloch

Face all yellow; the black vittae of the mesonotum are postsutural; the disc of the scutellum is dark brown; front tibia of male with a spongy swelling on posterior side but the tarsi are normal . . . . *semifusca* Malloch

Clusiosoma (Clusiosomina) puncticeps Malloch

Fig. 27*a–c*

Clusiosoma (*Clusiosomina*) *puncticeps* Malloch 1939. Linn. Soc. N. S. Wales, Proc. 64: 426–427.

This very distinctive species has been adequately described by Malloch. It is readily separated from all known *Clusiosoma* by the peculiar process at the apex of each front metatarsus of the male (Fig. 27*a*) and by the characters given in the above key. The female ovipositor has not been described in the literature. A discussion of this may be of value here. The ovipositor is very short (Fig. 27*b*) and peculiarly modified; the extended length is about 2.5 mm. The piercer is about 0.66 mm. long by 0.19 mm. wide. It is very blunt at the apex and possesses a pair of large conspicuous spines which arise just before the tip (Fig. 27*c*); these spines are about 0.09 mm. in length. A series of short bristles occur on each side just behind

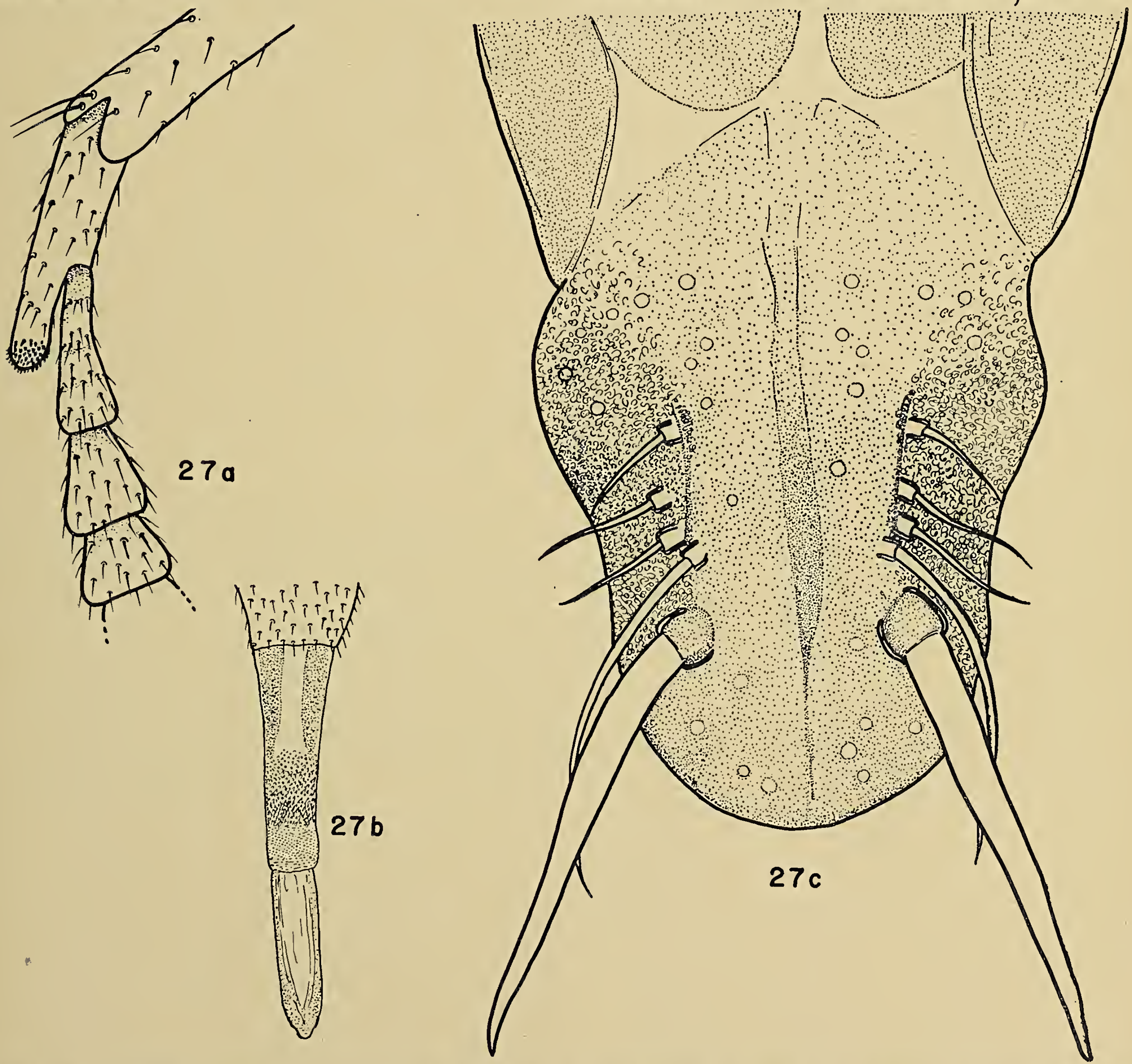


FIG. 27. *Clusiosoma* (*Clusiosomina*) *puncticeps* Malloch: a, front tarsus of male; b, ovipositor, full length; c, apex of ovipositor.

the spines. The tip of the oviduct is about 0.15 mm. from the apex of the piercer. The dorsal edges of the piercer fold onto the venter for a short distance about opposite the end of the oviduct. The inversion membrane is about 1.0 mm. long by 0.3 mm. wide measured at its broadest point. The scales are short and blunt and have a row of microscopic (visible under oil immersion) teeth at their apices. The scales extend to within 0.47 mm. of the base of the eighth segment. The basal half of this segment has a reticulated pattern on the sides where the rod-like sclerotization occurs. The basal portion of the ovipositor is about 0.9 mm. long by 0.9 mm. across its base.

Length: Body and wings, 4.0–4.3 mm.

TYPE LOCALITY: Gosford, New South Wales, in wild fig.

Type in the British Museum.

Specimens were sent in by Mr. Krauss from Narara, New South Wales, Jan. 17, 1947, ex *Ficus stephanocarpa*(?) (C. P. Hely).

EUPHRANTA Loew

Euphranta Loew 1862. Mon. Europ. Bohrfl. 28.

This genus is distinguished from other Trypetinae which have plumose aristae and four scutellar bristles by having the pleurotergite (lateral divisions of the metanotum) pilose, by having a strong sternopleural bristle, by having the pair of superior fronto-orbital bristles located well above the middle of the front and with two pairs of strong incurved inferior fronto-orbitals.

GENOTYPE: *Euphranta connexa* (Fabricius).

Euphranta minor Hendel is the only species of this genus which has been previously reported from Australia. A second, apparently undescribed species, is in the Krauss collection. It is distinguished from *minor* by the following characters:

Larger species, length of body 6.5–8.0 mm.; mesonotum yellow to rufous with conspicuous black markings; abdomen predominantly shining black and covered with black hair; the brown crossband over the r–m crossvein extending to the wing margin and fusing with the brown band which extends over m crossvein (i.e., the hyaline band through the middle of the wing ends at vein M_{3+4}); the apical hyaline spot small, not extending into cell 2d M_2 and scarcely into cell R_3 (Fig. 28*b*); all of the hind tibiae and the bases of the middle pair blackish........... *linocierae* n. sp.

Smaller species, 4.0 mm. in length; thorax reddish-brown with no black markings on the mesonotum; abdomen rusty colored and yellow-haired; the brown band over r–m not extending to the wing margin and not connecting with the band over m (the hyaline band across the middle extends to the wing margin); the apical hyaline spot larger and extending well over the tips of veins R_{4+5} and M_{1+2}; the legs all yellow. . *minor* Hendel

Euphranta linocierae n. sp.

Fig. 28*a–d*

This species is related to *Euphranta minor* Hendel and differs in respects pointed out in the above comparison.

MALE. *Head:* Chiefly yellow to rufous, median portion of the front discolored with brown to black; lower portion of the face with a transverse brown to black band just above the oral margin. Front about one and one-third times longer than wide and slightly expanded on the lower portion. The antennae are yellow-red and the third segment is almost equal in length to the face; the longest hairs on the arista are about as long as the width of the third antennal segment. The face is rather deeply concave in the central portion; from a direct lateral view the bottom of the concavity is below the eye margin (Fig. 28*a*). The cheeks are about equal to slightly narrower than the width of the third antennal segment. The genal bristles are strong; they are almost as well developed as the anterior pair of inferior fronto-orbitals.

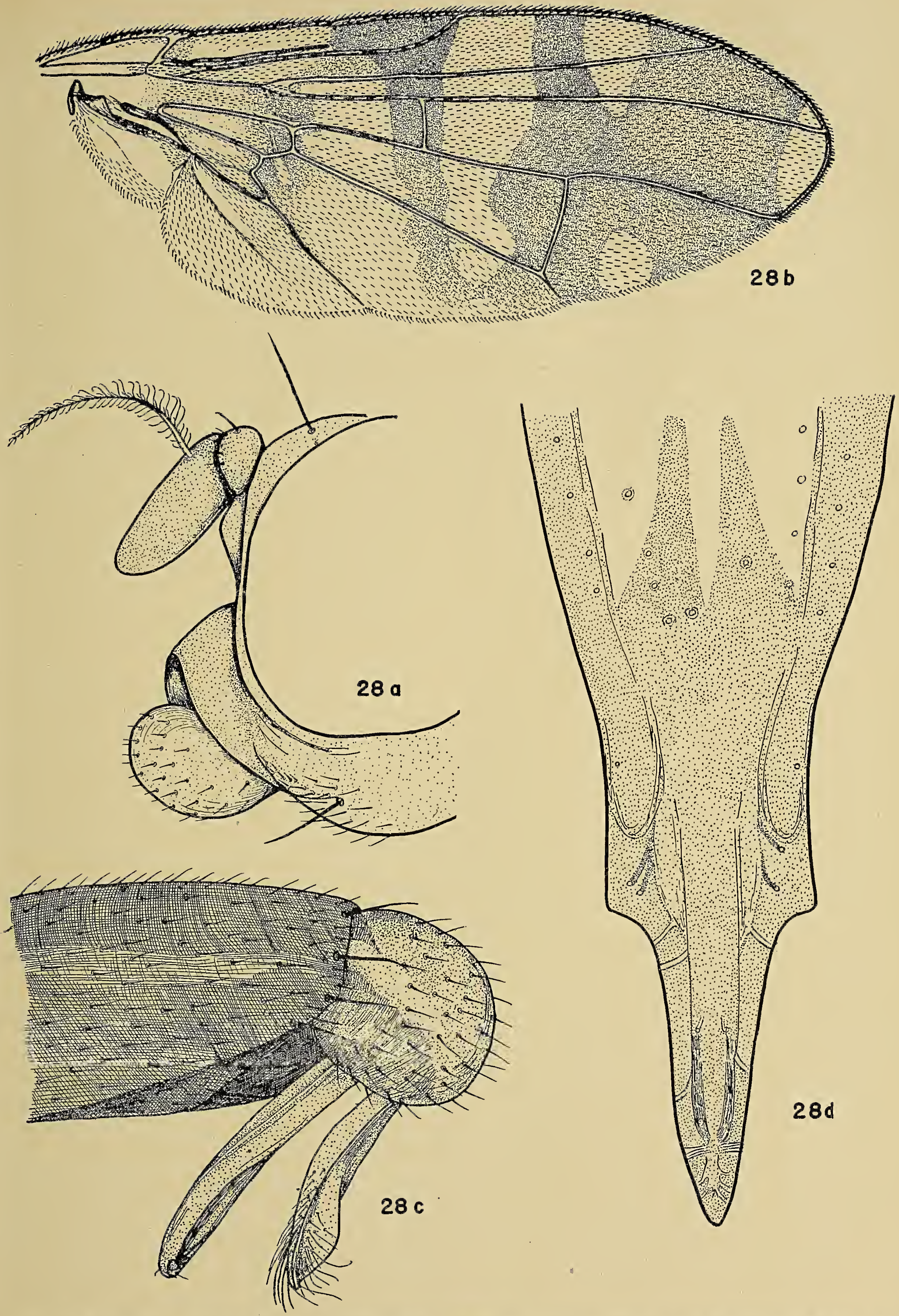


FIG. 28. *Euphranta linocierae* n. sp.: a, female head, lateral; b, wing of male; c, male genitalia, lateral; d, apex of ovipositor.

The compound eyes are oval in shape. The head bristles are all black. *Thorax:* Chiefly yellow to rufous, gray pollinose on the dorsum. A pair of broad subshining black postsutural vittae extends longitudinally through the area bounded on the sides by the inner posterior supra-alar bristles and by the dorsocentrals. The black vittae are broadly interrupted at the suture, and near their inner anterior apices they connect with a less distinct brown to blackish vitta which extends just inside the inner edges of the suture to the front margin of the mesonotum between the scapular bristles. The mesonotum also has a rather large presutural black spot just behind each humerus. The humeri and the scutellum are yellow. There is also a quadrate-shaped yellow spot, bounded by the prescutellar and the dorsocentral bristles, on the hind portion of the mesonotum. A transverse line of brown extends across the hind margin of the mesonotum almost connecting with the posterior apices of the lateral vittae. The dorsocentral bristles are situated distinctly behind the anterior supra-alars. The four scutellar bristles are stronger than any of the other thoracic bristles. The scutellum has a few very short black hairs around the margin and a clump of black hairs on each side just behind the basal pair of bristles. The metanotum, metapleura, lower portion of the sternopleura, and median portion of the hypopleura are brown to blackish in color. The halteres are yellow. *Legs:* Largely yellow, hind tibiae and bases of middle pair blackened. *Wings:* As described above and as shown in Figure 28*b*. The basal portion is chiefly hyaline, and a faint brownish infuscation extends across the base just in front; another brown spot covers the forking of the radial sector and the base of vein M_{3+4}. The stigma is all brown. The front margin of the wing has two hyaline indentations, one in the anterior one-third of the fourth costal section (cell R_2) extending transversely to vein M_{3+4}; the other mark is smaller and extends from the margin near the outer two-thirds of the fourth section into the top edge of cell R_5. One hyaline indentation occurs on the hind margin and extends about two-thirds through cell 2d M_2. Vein R_{4+5} is rather sparsely bristled to a point about opposite the halfway point between the r–m and m crossveins. *Abdomen:* The entire fifth tergum and the sides of the other terga are shining bluish-black. The median portion of terga 1 to 4 is rufous in ground color and densely grayish pollinose. The vestiture is all black; the apical margin of the fifth tergum has a ring of about 12 rather strong bristles. *Genitalia:* Yellow to reddish. The ninth segment is plainly visible from a dorsal view and is globose in shape. The anal area (tenth segment or proctiger) and the surstyli (the extended lower margins of the ninth tergum) are very elongate and slender (Fig. 28*c*). The anal region is thickly yellow pilose.

Length: Body, 6.5–8.0 mm.; wings, 5.5–6.5 mm.

FEMALE. Very similar to the male. In the two specimens at hand the brown band across the lower portion of the face is interrupted in the middle. The sides of the fifth and sixth terga are yellow, the median portion is polished black. The coloration of the body is otherwise as in the males. *Ovipositor:* Short and rather broad, the extended length slightly less than 3.0 mm. The piercer measures about 0.75 mm. long by 0.24 mm. wide and is very characteristic in shape. It is very sharply constricted toward the apex, the constriction beginning about 0.19 mm. from the tip (Fig. 28*d*). The preapical setae are tiny and inconspicuous, and they are situated about 0.04 mm. from the apex of the piercer. The oviduct ends about 0.13 mm. from the apex. The inversion membrane, which is torn on the specimen which has been dissected, is apparently about 1.2 mm. long by 0.3 mm. wide. The scales are rather sharp pointed and extend to within 0.6 mm. of the base of the segment.

Holotype male, allotype female, and two

paratypes (one male and one female): Cairns, Queensland, ex *Linociera ramiflora*, Sept., 1949.

Type in the United States National Museum. Allotype and one paratype in the Bishop Museum, Honolulu, T. H., and one paratype in the University of Hawaii collection.

HENDELINA new name

Pseudopheniscus Hendel 1913. Suppl. Ent. 2:82.
Pseudospheniscus Hendel 1914. Wien Ent. Zeitung 33:83.

Pseudopheniscus Hendel was an erroneous spelling which was corrected to *Pseudospheniscus* by Hendel in 1914. The genus was based upon *sexmaculata*, which Hendel transferred from *Spheniscus* Becker (*Spheniscomyia* Bezzi = change of name for *Sphaeniscus* Becker 1908—emended to *Spheniscus* by Bezzi 1913—nec *Spheniscus* Brisson 1760). Hendel (1915: 451) stated that through an oversight he had indicated a false type for *Pseudospheniscus*—that the genotype should be *angulatus* Hendel, not *sexmaculatus* Macq. The name *Pseudopheniscus* would therefore be a synonym of *Spheniscus* Becker because of the error made in choosing the original genotype.

The name *Pseudospheniscus* Hendel (as has been used in literature since Hendel corrected the spelling) is preoccupied in the birds by *Pseudospheniscus* (Ameghino, 1906).

If the original spelling *Pseudopheniscus* is accepted, the name would have to fall as a synonym since the only included species, *sexmaculata*, belongs in *Spheniscomyia*. If the corrected spelling *Pseudospheniscus* is accepted, the name has to be discarded as a homonym.

This is apparently the first published record of this genus from Australia. Mr. Alan May (in correspondence) has informed me that "two species of *Pseudospheniscus bifidus* Bezzi and *fossatus?* occur in Australia both being represented in Perkins' collection and both taken in North Queensland." I doubt that *fossatus* (Fabricius) actually occurs in Australia and believe that the specimens in Perkins' collection may belong to the new species discussed below.

The genus is distinguished from other Trypetinae by having four marginal scutellar bristles, by possessing dorsocentral bristles, by having two to three pairs of inferior fronto-orbital bristles and two pairs of superior fronto-orbitals, by the comparatively weak ocellar bristles which are much shorter than the superior fronto-orbitals, and by having the front narrower than the eyes and usually two or more times longer than wide.

The genus is closely related to *Neanomoea* Hendel and is distinguished by the narrow front. The Australian species at hand has the front about two times longer than wide and much narrower than the eyes. In *Neanomoea* the front is broader than the eyes and is only about one and one-half times longer than wide. It differs from *Anomoea* Walker, as characterized by Malloch (1939*b*:448–449), by not having the antepenultimate section of the fourth vein (M_{1+2}) bent downward just before the r–m crossvein. It differs from *Phagocarpus* Rondani as characterized by Bezzi (1913: 130–131), Shiraki (1933: 182–184), and Hering (1938: 20) by not having the discal cell (1st M_2) sharply pointed on lower apex or the m crossvein oblique in position.

GENOTYPE: *Hendelina angulata* (Hendel).

KEY TO KNOWN PACIFIC SPECIES OF *Hendelina*

1. Costal margin of wing not all black, with two or more hyaline indentations or marks 2
   Costal margin entirely black from the base of the wing to the middle of cell R_5 (Fiji) .... *bifida* (Bezzi)
2. Costal cell containing one or two hyaline marks; no black streak extending obliquely through cell R_5...... 3
   Basal half of wing, excluding anal and auxiliary cells, all black; cell R_5 with an oblique streak extending from

vein R_{4+5} to the apex of M_{1+2} (Fig. 29*a*) 5

3. Costal cell with two hyaline spots; cell R with a small round spot just behind the r–m crossvein; no wedge-shaped hyaline mark on costal margin just beyond stigma; mesopleura yellow (Fiji) .... *mesopleuralis* (Malloch)

Costal cell with one hyaline mark; no spot in cell R; a wedge-shaped spot just beyond stigma; mesopleura black 4

4. Mesonotum densely brownish-gray pollinose, with three dark vittae; vein R_{4+5} bristled only to the r–m crossvein (New Guinea) .... *taylori* (Malloch)

Mesonotum entirely shining black; vein R_{4+5} setulose nearly its entire length (New Guinea) . . . *erebia* (Hering)

5. Wing markings as in Figure 29*a*. The black margin at the wing apex continuous with the vertical black band through the wing; the hyaline mark in the apical portion of the wing not inverted Y-shaped and comparatively broad, extending from the middle of cell R_5 to near lower apex of cell M_2; cell M_2 almost all hyaline at its apex; the hyaline transverse markings toward middle of wing extending into the apical portion of cell 1st M_2 on the top as well as the lower margin; the black coloration extending to the apex of cell M_4 in the middle and fills all of this cell except the lower edge (Australia) .... *australina* n. sp.

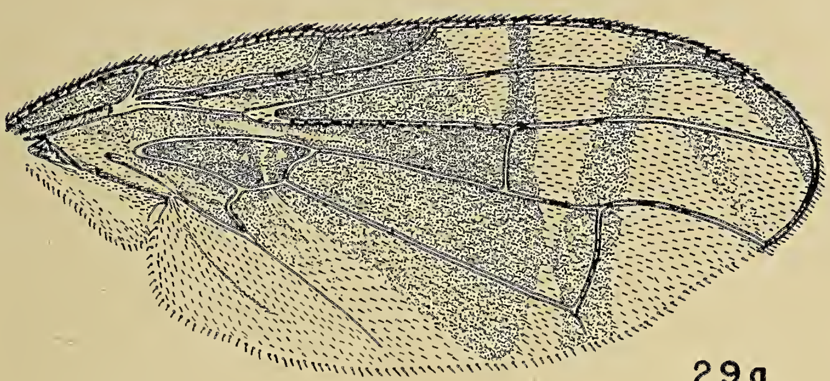
Wing markings as in Figure 30. The black margin at the wing apex not continuous with the black vertical band; the hyaline mark in apical portion in the form of an inverted Y and comparatively narrow, extending from lower portion of cell R_5 to about middle of cell M_2. The hyaline "arms" of the Y-shaped mark about equal in width to the oblique, black streak which sets off the Y, cell M_2 almost all black at its apex; the hyaline transverse markings not extending into cell 1st M_2 so this cell is entirely black; the black markings not extending to the margin in cell M_4, except at the upper corner, and the lower two-fifths of this cell hyaline (Solomon Islands) .... *apicifasciata* (Malloch)

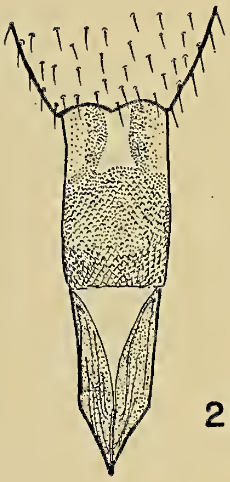
Hendelina australina n. sp.

Fig. 29*a–c*

This species appears to be more closely related to *H. apicifasciata* (Malloch) (Fig. 30) than to any other known species. It is easily separated by the differences in the dark pattern in the wings as pointed out in the above key.

MALE. Chiefly black species. *Head:* Yellowish to rufous, concave portion of the occiput black. Front about two times longer than wide, and with three pairs of inferior fronto-orbital bristles and two pairs of superior fronto-orbitals. Ocellar bristles moderately developed and slender. They are about half as long as the superior fronto-orbitals. Face silvery pubescent, median portion flat and straight, sides rather deeply grooved. Antennae yellowish, third segment about two times longer than wide. *Thorax:* All black except for the yellowish humeri. Pleura subshining, mesonotum and scutellum grayish pollinose. Dorsocentral bristles placed distinctly posterior to the anterior supra-alar bristles. The scutellum has four strong bristles and a few small marginal hairs. Halteres black. *Legs:* Front pair all yellow except for slight brownish discoloration on the outside of each femur. Middle and hind femora and the bases of the tibiae black, except for extreme tips of middle femora which are yellow. Middle and hind tarsi and apical three-fourths of the tibiae yellow. The spurs of the middle tibiae are well developed and are about half as long as the basitarsi. The front femora have a row of moderately long bristles evenly spaced along the exterior ventral portion. *Wings:* (Fig. 29*a*.) Basal half, excepting anal and auxiliary lobes and posterior one-third





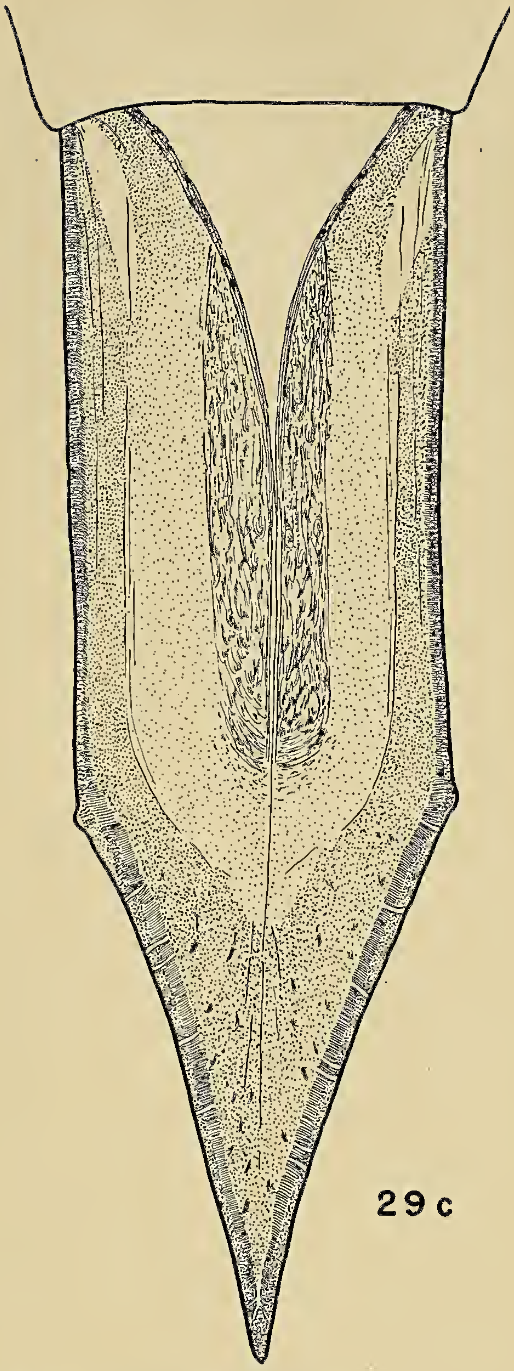


FIG. 29. *Hendelina australina* n. sp.: a, wing; b, ovipositor, full length; c, apex of ovipositor.

of cell M_4, all black. Costal margin with a broad, wedge-shaped, hyaline mark extending to vein R_{4+5} at the r–m crossvein. A second hyaline indentation extends from the costal margin in the middle of cell R_2 through cells R_2, R_3, R_5, and to nearly the middle of the apical part of cell 1st M_2. This mark is typically interrupted by brown to black coloration in the middle of the apex of 1st M_2 and continues again through the remainder of this cell to the wing margin through the apex of cell M_4. In some specimens this hyaline mark is continuous from the costal to the hind margin of the wing

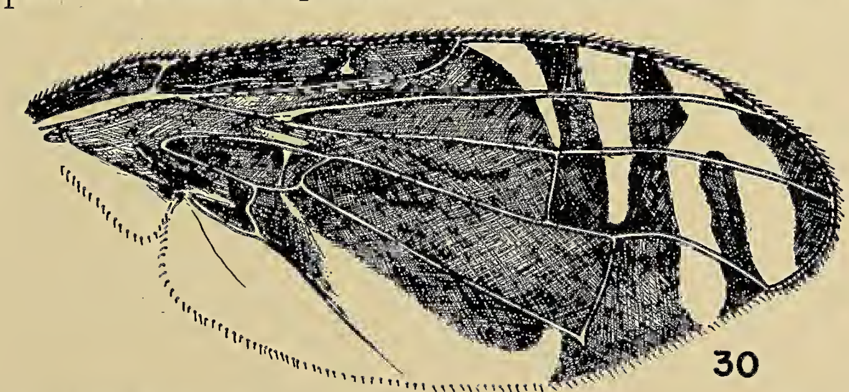


FIG. 30. *Hendelina apicifasciata* (Malloch): wing. (Copied from original.)

and is not interrupted in the middle of 1st M_2. The apical portion of the wing is hyaline except for a narrow brown to black band extending transversely through the apical third of the wing and continuing around the costal margin to nearly the middle of cell R_5 and for the narrow black streak which extends obliquely from the apex of vein M_{1+2} to vein R_{4+5}. Vein R_{4+5} is setulose only to the r–m crossvein. Vein R_3 is very slightly wavy and the ultimate section of vein R_{4+5} is curved upward in the middle portion. The third costal section (stigma or subcostal cell) is about two-thirds as long as the second section. The r–m crossvein is situated about its own length from the end of the discal cell (1st M_2), and the m crossvein is vertical in position. The narrowed portion of the cubital cell is equal to slightly more than half the length of the r–m crossvein. Vein Cu_1+1st A extends to the wing margin. *Abdomen:* All black, polished on the fifth tergum and subopaque on terga 1 to 4. Rather thickly covered with short, black reclinate hairs and with six to eight strong bristles on the apical margin of the fifth tergum. The genitalia have not been studied carefully. They are tinged with yellowish and the lobes of the ninth segment are slender, rather elongate, and bear long hairs at their apices.

Length: Body, 4.2 mm.; wings, 3.8 mm.

FEMALE. Very similar to the male. Terga 4 and 5 and the basal segment of the ovipositor (segment 7) are polished black. The ovipositor is inconspicuous from a dorsal view—just the basal portion is visible. The exposed portion of the ovipositor is about equal in length to the fifth abdominal segment. The extended ovipositor is short and thick (Fig. 29*b*), and the tip of the piercer is characteristically tapered. The full length of the ovipositor is about 1.9 mm. The piercer is approximately 0.6 mm. long by 0.18 mm. at its broadest point. The basal three-fifths of the piercer is straight sided. At the point where the piercer begins to taper, a tubercle is located on each side; beyond (at the apical two-fifths) the piercer tapers abruptly into a sharp point (Fig. 29*c*). The opening of the oviduct is about 0.18 mm. from the apex of the piercer, and there are no preapical setae present. The inversion membrane is about 0.6 mm. long by 0.26 mm. wide; the scales of the rasper extend to about 0.18 mm. from the base of the segment. The remainder of this segment is densely covered with scales which vary in shape from thorn-like on the apical portion, triangular in the middle, and obtuse at the basal part of the rasper. The basal segment of the ovipositor is about 0.75 mm. long by 0.9 mm. across its hind margin. The spiracles are located about 0.3 mm. from the base of the segment.

Length: Body, 4.2–4.5 mm.; wings, 3.8–4.0 mm.

Holotype male, allotype female, and 14 paratypes (10 females and 4 males): Hartley's Creek, N. Queensland, ex *Primna nauseosa*, Feb., 1950.

Type, allotype, and two paratypes are in the United States National Museum. Three paratypes are in the Bishop Museum, Honolulu, T. H.; three in the Board of Agriculture and Forestry collection, Honolulu, T. H.; two in the Hawaiian Sugar Planters' Association collection, Honolulu, T. H.; three at the University of Hawaii; and one in Dr. M. Hering's collection at the University of Berlin.

RIOXA Walker

Rioxa Walker 1857. Linn. Soc. Lond., Proc. 1: 35.

The members of this genus are distinguished from other Trypetinae which have six scutellar bristles and a plumose arista by having veins R_{1+2} and R_{4+5} setulose but with the setulae on R_{1+2} not extending onto the node of the radial vein, by having the wings chiefly brown to black with round hyaline spots in the middle of the wing and hyaline incisions around the margin, by having the dorsocentral bristles placed distinctly behind the anterior supra-alars, by having the mesonotum scarcely longer than wide, by the lack of pile on the scutellum, and by having two pairs each of superior and inferior fronto-orbital bristles. Malloch (1939*a*) removes *Termitorioxa* from *Rioxa* on the basis of the differences in the frontal bristles and the narrower mesonotum and by the presence of small hairs on the scutellum. According to Hendel (1928) (also Malloch, 1939*a*) three Australian species belong in the genus *Rioxa*. He assigns them to the subgenus *Dirioxa* Hendel. Malloch says that *Rioxa araucariae* Tryon and *R. jarvisi* Tryon do not belong in *Rioxa*. It is now quite apparent that *bicolor*, also, does not fit into this group, but belongs to the genus *Acanthoneura*.

GENOTYPE: *Rioxa lanceolata* Walker.

KEY TO AUSTRALIAN *Rioxa*

1. The hyaline spots in cell R_5 are nearly as wide as the cell (Fig. 32*a*) .... *pornia* (Walker)
   The hyaline spots are comparatively small, about half as wide as cell R_5.. 2
2. The hyaline spot in cell R_5, just above the m crossvein, is connected with the large wedge-shaped hyaline mark in cell 2d M_2; the hyaline mark in the apex of cell 1st M_2 not extending across the cell.......... *testacea* Hendel
   The spot in cell R_5, above the m crossvein, is isolated from the wedge-shaped mark in 2d M_2; the hyaline mark at the apex of 1st M_2 extends across the cell through cell M_4 to wing margin .... *confusa* n. sp.

Rioxa (Dirioxa) confusa n. sp.

Fig. 31*a–d*

The *Rioxa* of Australia have not been thoroughly studied and this species has never been properly placed. It had previously been considered to be *Rioxa pornia* (Walker) but was found to be quite a different species when the true identity of *pornia* was ascertained. The species was then considered to be *bicolor* Macquart, which had been assigned to *Rioxa* by Hendel (1928) and Malloch (1939*a*). The wing coloration of *R. confusa* fits Macquart's figure (1855, pl. 7, fig. 7) rather closely in most respects, allowing for the inaccuracy in detail characteristic of many of Macquart's figures. *R. confusa* wings differ by having smaller, rounder spots in cell R_5, by having the hyaline mark in the apex of cell 1st M_2 enlarged in the upper portion and not just a narrow streak across the apex, by having the brown coloration extending from cell 1st M_2 into cell M_4 not reaching to the wing margin, and by having the hyaline marking in cell M_4 extending to the middle part of cell 1st M_2 (Fig. 31*a*).

R. confusa is apparently more closely related to *R. testacea* Hendel than to any other known species. It is distinguished by the characters given in the above key.

MALE. A predominantly yellow species with dark brown to black maculations in the wings. *Head:* The face is one and one-half times longer than wide; the lower portion is discolored with red. The face is straight on the upper two-thirds and tumescent below. The gena are about as wide as the third antennal segment. *Thorax:* Entirely clear yellow, subshining, very lightly grayish pollinose. *Legs:* All yellow. *Wings:* As given in the above key and notes and as shown in Figure 31*a*. The first costal cell is hyaline and bare; the second cell is covered with microtrichia and is yellowish-fumose in the basal portion. The marginal fringe on the squamae is made up of gray to blackish hairs. *Abdomen:* The first three terga are yellowish; the fourth is yellow to rufous in the middle and brown to black on the sides. The fifth tergum varies from yellow to rufous in the middle and brown to black on the sides to chiefly brown to black with a tinge of rufous in the middle at the apex.

Length: Body, 5.0 mm.; wings, 5.5 mm.

FEMALE. Very similar to the male. *Ovipositor:* In pinned specimens just the basal segment is visible. It is dark brown to black

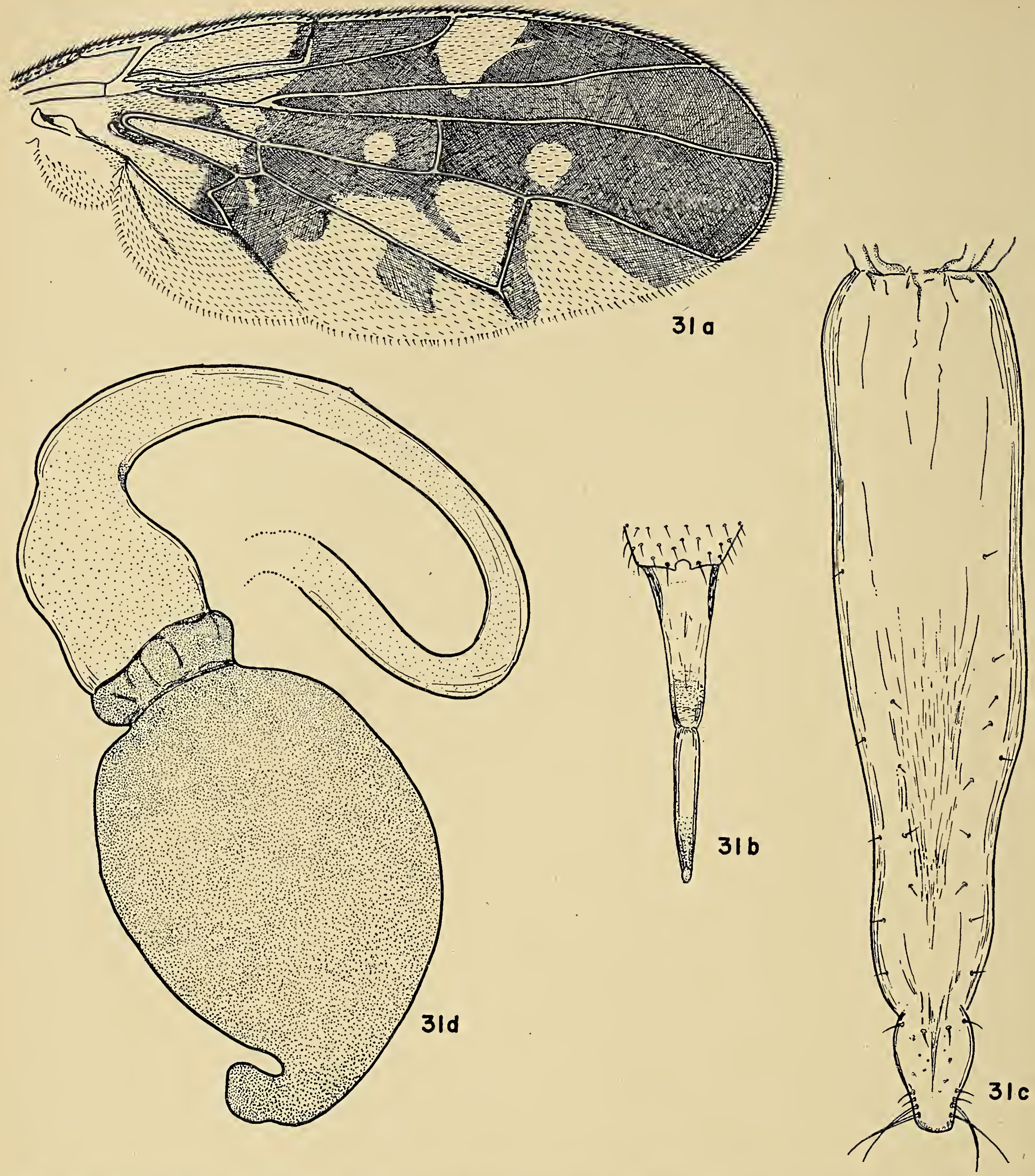


FIG. 31. *Rioxa* (*Dirioxa*) *confusa* n. sp.: a, wing; b, ovipositor, full length; c, apex of ovipositor; d, a spermatheca of female.

and is nearly as long as the combined lengths of segments 3 to 5. The extended ovipositor (Fig. 31*b*) is about 2.27 mm. long. The piercer measures about 0.7 mm. in length and is very blunt at the apex and somewhat swollen in the middle. At its widest point the breadth is about 0.15 mm. The piercer is slightly constricted a short distance behind the apex, at about the end of the oviduct (Fig. 31*c*). The piercer has four pairs of setae located almost at the apex; the distad pair are long and strong, extending well beyond the tip of the piercer. The basal pair are short and scarcely one-fourth as long as the distad pair. The apex of the oviduct is about 0.09 mm. from the tip of the piercer. A pair of sublateral

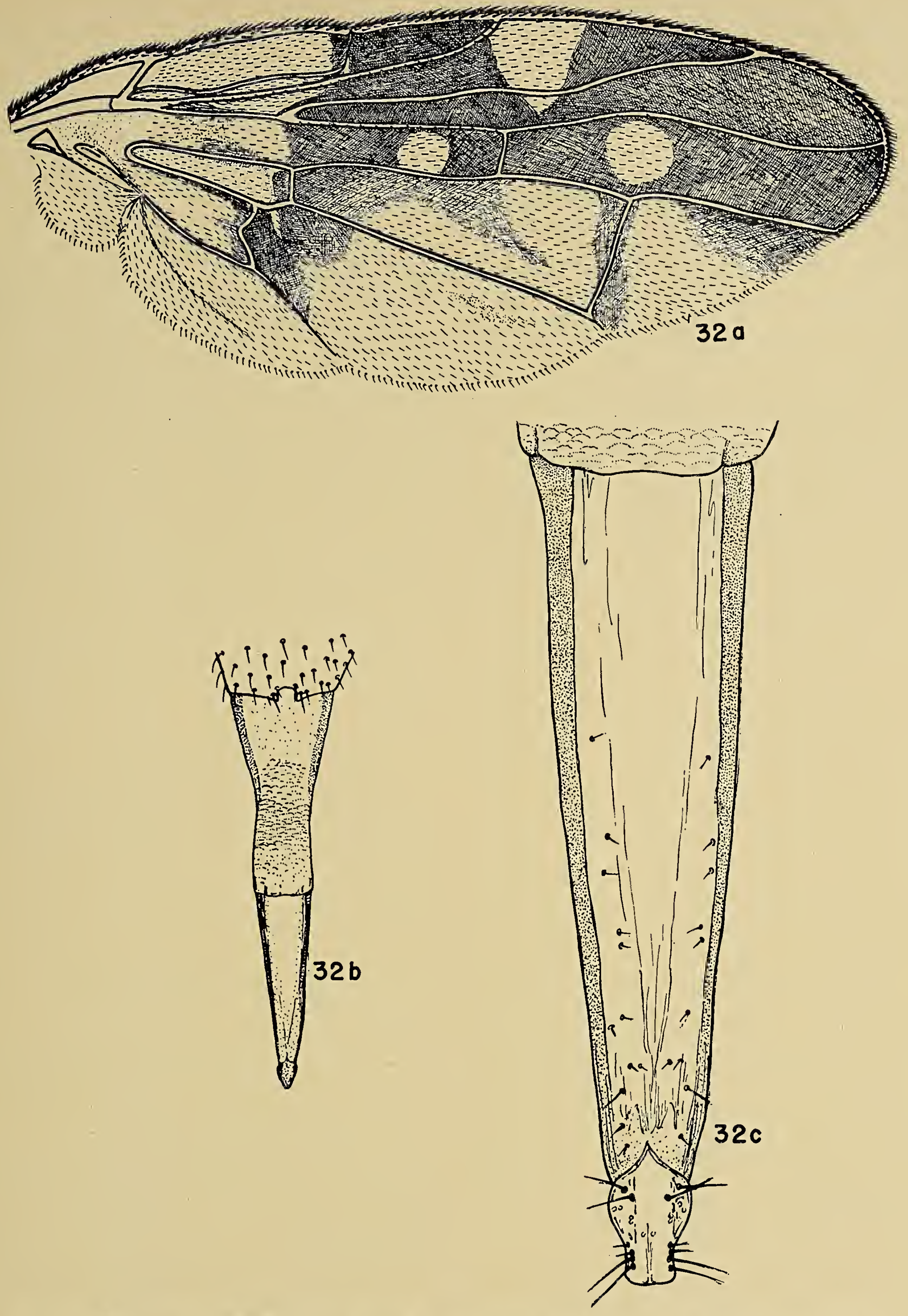


FIG. 32. *Rioxa pornia* (Walker): a, wing; b, ovipositor, full length; c, apex of ovipositor.

setae are situated on each side just beyond the oviduct opening, and a row of six to eight setae are situated near the sides of the ventral margin and extend basad to beyond the middle of the segment. The inversion membrane is about 0.77 mm. long by 0.32 mm. wide. The rasper is not made up of scales but is composed of numerous raised ridges which bear microscopic dentations on their hind margin. The rasper extends about half the length of the segment, or about 0.38 mm. from the base. The basal segment of the ovipositor is about 0.8 mm. long by 0.8 mm. at its widest point. The spiracles are located very close (0.09 mm.) to the base of the segment. The spermathecae are distinctive in shape (Fig. 31*d*). They are apparently three in number but one specimen studied had four.

Type male, allotype female, and 115 paratypes from Atherton Tableland, Queensland, ex *Planchonella* sp.(?), Nov.–Dec., 1949; 30 paratypes from Julatten, Queensland, ex *Amorphospermum antilogum*, and 2 from Mowbray River, Queensland, ex *Capparis lucida*, Feb., 1950.

Type, allotype, and a series of paratypes are in the United States National Museum collection. The remainder are deposited in the following collections: Board of Agriculture and Forestry, Honolulu, T. H.; Bishop Museum, Honolulu, T. H.; Hawaiian Sugar Planters' Association, Honolulu, T. H.; Australian Museum, Sydney; University of Hawaii; Dr. H. K. Munro, Pretoria, South Africa; Dr. M. Hering, University of Berlin; and Mr. J. E. Collin, Newmarket, England.

Rioxa pornia (Walker)

Fig. 32*a–c*

Trypeta pornia Walker 1849. List Dipt. Brit. Mus. 4: 1039.

Trypeta musae Froggatt 1899. Agr. Gaz. N. S. Wales: 501.

Tephritis psidii (Froggatt) Tryon 1904-5. An. Rep. Entom.: 71.

Dacus musae (Froggatt) Gurney 1912. Agr. Gaz. N. S. Wales: 75.

Rioxa musae (Froggatt) Tryon 1927. Roy. Soc. Queensland, Proc. 38: 216.

This species is readily distinguished by the large spots in cell R_5, the paler brown maculations in the wings, and the different coloration of the abdomen. In general details it will fit the above description of *R. confusa* n. sp. The wing maculation is as given in the above key and shown in Figure 32*a*. The first two abdominal segments are yellow to cream. The third is yellow in the middle, this mark expanding posteriorly to cover most of the hind margin; a wedge of black extends on each side from the lateral margins about one-third the distance across the anterior margin. The fourth and fifth segments of the male are entirely subshining black. The female has a narrow yellow mark across the front margin of the fourth tergum. *Ovipositor:* Shining black; the visible portion is not quite as long as terga 4 plus 5. The extended ovipositor is almost identical with that of *confusa*. No satisfactory specific characters have been found in the ovipositors. That of *pornia* (Fig. 32*b–c*) appears to have more distinct dentations on the rasper, the longitudinal bars in the basal part of the inversion membrane appear more heavily sclerotized, and the piercer is more straight sided; these may be individual variations.

Length: Body, 5.0 mm.; wings, 5.5–6.0 mm.

TYPE LOCALITY: Port Stephens, New South Wales.

Type in British Museum.

Specimens were received from Mr. Krauss from Gosford, New South Wales, ex "feijoa fruit," Apr., 1950 (Krauss); and Narara, New South Wales, "trapped," Nov. 29, 1933 (C. P. Hely).

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Asterospicularia laurae, n. gen. et n. sp., the Type of a New Family of Alcyonarians with Stellate Spicules

HUZIO UTINOMI[1]

AMONG THOSE SPECIMENS of Alcyonaria obtained during my trip to Formosa in 1938, there is an interesting form which cannot be referred to any known genus of the group. It is represented only by a single specimen obtained on the coral reef at Daijubô, southernmost promontory of Formosa, on June 14, 1938. Superficially it shows a resemblance to the genus *Capnella* in the mode of branching and in the appearance of polyps. Closer examination of the total specimen and sectioned preparations, however, has revealed that the coenenchyma as well as the polyp wall has a honeycombed texture filled with numerous stellate spicules and that the tentacles bear no trace of pinnules. Such characters are entirely unknown in the whole group of Alcyonaria, so I propose to institute for this form a new genus and even a new family.

The following description is based on a perfect specimen which was taken as the type.

EXTERNAL APPEARANCE

The specimen (Fig. 1*a*) is in the form of a small colony of bushy growth and has a yellowish white colour in alcohol. The base of the colony is broadened, flattened, and about 12 mm. in longest diameter. From the flattened upper surface of the short columnar stem arise nine large and small polyp-bearing lappets. Each of the lappets is mushroom-shaped; each consists of a polyp-bearing rounded capitulum and a short wide sterile stalk, the former being marked off sharply from the latter. In the largest lappet, the capitulum is about 6 mm. in diameter and 5 mm. in height, and the stalk is about 8 mm. in diameter and 5 mm. in height. The total height of the colony is about 13–17 mm.

No polyp dimorphism is found. The autozooids are closely set and rather large, being up to 1 mm. in diameter and 1.5 mm. in height. They are apparently capable of considerable contraction, and they look like papillae provided with a rather large central mouth surrounded by eight-lobed tentacles (Fig. 1*b*). The whole surface of the trunk of the zooid is thickly covered with stellate spicules of sub-equal size which are continued onto the dorsal surface of the tentacles. The spicules are evenly scattered as in the Xeniidae and do not form any densely packed row or ridge along the intermesenteric area (Fig. 1*c*).

The tentacles, in the contracted state, appear oval in side view and measure about 0.5 mm. long and 0.37 mm. wide (Fig. 1*d*). The pinnules are missing. Careful microscopic examination of serial sections of the tentacle reveals that from 8 to 10 opaque rounded bodies are imbedded slightly beneath the oral surface of the tentacles (Fig. 2*c*). These bodies are scattered here and there in the peripheral layer, but are closely united with one another in the deeper layer; they are continuous with the coelenteric cavity below the mouth. The interior is filled with numerous zooxanthellae and endoderm cells, and there is no connection between this region and the epidermis. Here the epidermis shows no sinus or indentation suggesting the presence of pinnules. Thus I consider this body

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[1] Seto Marine Biological Laboratory, Sirahama, Wakayama-Ken, Japan. Manuscript received September 6, 1950.

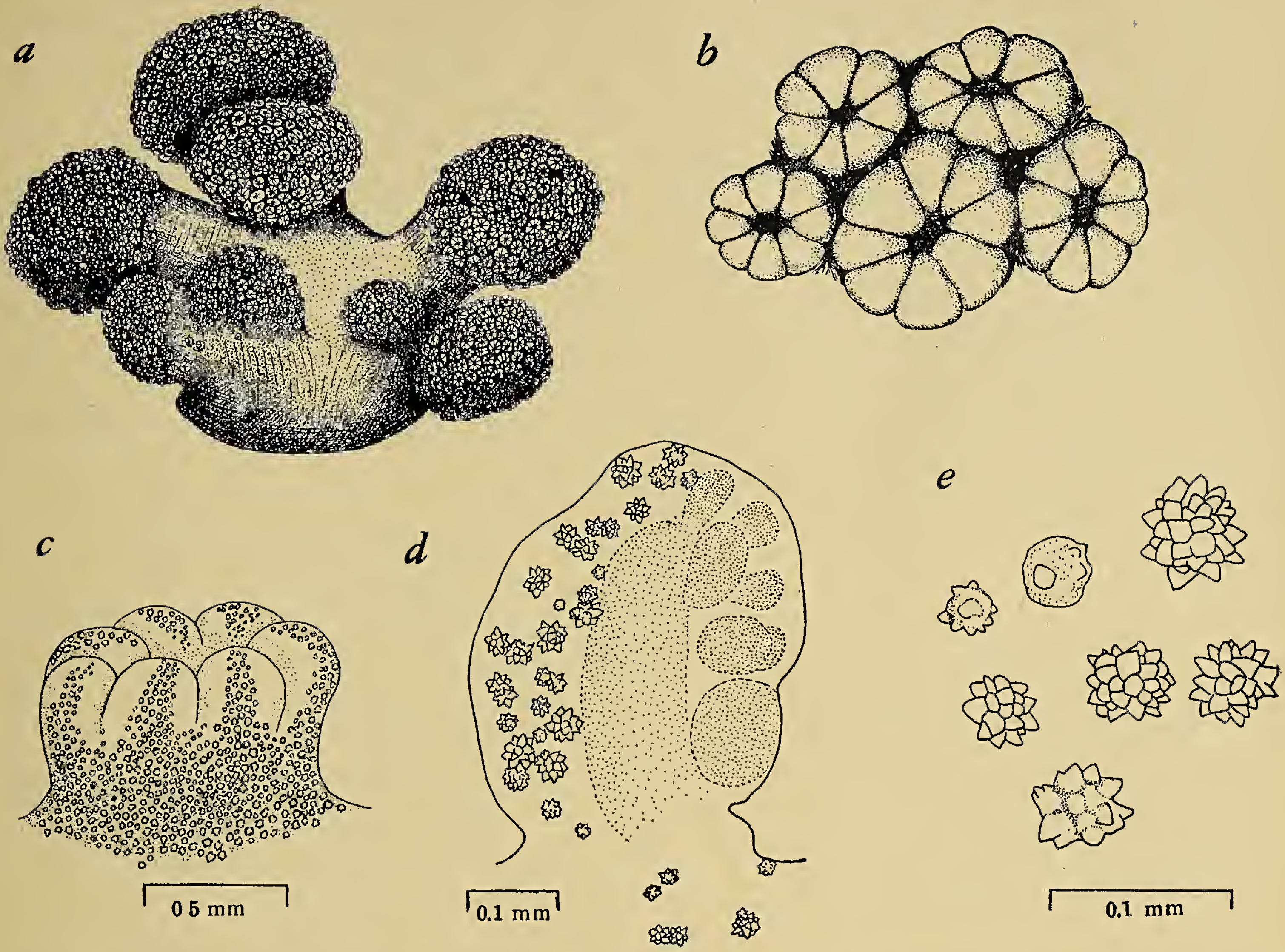

FIG. 1. *Asterospicularia laurae* n. gen. et n. sp.: *a*, holotype; *b*, five polyps, enlarged, showing the crown of contracted tentacles; *c*, lateral view of polyp, showing the arrangement of spicules; *d*, section of tentacle with spicules on aboral side only; *e*, stellate spicules and derivatives.

to be merely the branch of the coelenteron and not the contracted pinnules.

The spicules (Fig. 1*e*) are stellate, exceptionally roughened spherules without any distinct process. They are distributed uniformly in the mesogloea of the coenenchyma, polyp wall, oral disc, and the aboral side of the tentacles. They measure about 0.03–0.05 mm. in average diameter and, as in most alcyonarians, are composed of calcium carbonate with a sparse organic matrix. This stellate spicule, which reminds one of the sphaeraster of the tetraxonid sponges or the stellate spicule of the didemnid ascidians, is unique in the group Alcyonaria, and it is quite different from the spicules found in other forms.

INTERNAL ANATOMY

For histological examinations, parts of the specimen were sectioned after decalcification in dilute acids. Because of poor staining, examination of the minor histological details was not possible.

The cross section of the main branch of the colony shows numerous lacunae of various sizes. The large lacunae are the direct continuations of the coelenteron of the principal polyps, while the smaller ones are the mesogloeal lacunae in the coenenchyma. The majority of the coenenchyma between the polyp bodies is strongly honeycombed by mesogloeal lacunae, which harbor spicules.

These honeycombed lacunae formed in the mesogloea are distinctly circumscribed and are mostly circular or oval to oblong in outline, as shown in Figures 2*a–d*. Each of these lacunae is beset with 1 to 8, rarely up to 10, stellate spicules, the number varying according to the size of each lacuna. In most other alcyonarians, however, the mesogloea is more or less compact and is beset, either densely or loosely, with spicules. Each spicule originates from a single scleroblast of ectodermal origin, so that the space or cavity for a spicule is closely fitted to the form of the spicule contained in it (Koch, 1878; Hickson, 1895; Woodland, 1905; Bock, 1938). In this alcyonarian, the spicular cavity is constant in form, irrespective of the number of spicules contained. Though I made no actual observations on the development of the spicules, there is no evidence in my preparations of the presence of a number of spicules in a single cavity originating from a single spicule-forming cell or scleroblast.

The body wall of the anthocodia is composed of three layers—an outer rather thick ectodermal layer, a very thick mesogloeal layer, and an inner endodermal layer. Of these, the mesogloea is divided into two layers—the outer layer (with large lacunae containing spicules) which lines the epidermis and the inner layer with smaller empty lacunae (Fig. 2*a*). The inner layer surrounding the coelenteric cavity forms a homogeneous fleshy mass scattered with free mesogloeal cells which are endodermal in origin. These cells are rather large, measuring 4 to 10μ in diameter, and contain darkly stained oval or spindle-shaped nuclei. It is highly probable that these mesogloeal cells of endodermal origin are the direct continuations of the endodermal cell-strings or canals (i. e., solenia) or their derivatives. Their function is probably to give nutrition to, and to perform excretion from, the mesogloea, as suggested by Hickson (1895), Pratt (1903, 1905), Bock (1938), and Gohar (1940*b*). No mesogloeal cell of ectodermal origin suggesting a nerve plexus could be traced.

The epidermis is coated with a thin outer cuticle and is rather thick. It occupies the area between the outer cuticle and the outer layer of the spicular cavities of mesogloea. Its basal lining is indistinct, since the outer contour of the superficial mesogloea containing the larger spicular cavities is very irregular. Thus the thickness of the epidermis is considerably varied in different parts of the body. As far as I have observed on the decalcified preparations, the epidermis appears to be formed of more than one layer of ectodermal cells. All these cells are irregularly arranged, and the ordinary supporting and interstitial cell layers cannot be distinguished. Also I have seen no nematocysts or mucous gland cells in the epidermis.

The mouth leads into a very short stomodaeum which penetrates deep into the coelenteron. The stomodaeum is lined internally by a thick columnar epithelium and is provided on the ventral side with the siphonoglyphe. In the stomodaeal region, the mesenteries have thickenings (the so-called muscle banners) on the ventral side situated closer to the stomodaeum than to the coelenteric wall. Further details of the structure of the mesenteric filaments could not be traced. All the mesenteries appear very thin and run straight from the lower end of the stomodaeum down to the bottom of the coelenteron.

The endodermal cells of the coelenteric and tentacular cavities, together with zooxanthellae contained within them, are very loosely packed in the whole space and form an undefined mass. The boundaries between the endodermal cells are, however, slightly visible. Apparently these cells do not form any ordinary epithelial lining on the coelenteric walls such as is found commonly in ordinary coelenterates. In the lower part of the coelenteron, however, the endodermal cells are situated close to the wall and mesenteries.

The internal canal system is not so well developed as in the Alcyoniidae. The endodermal cell-strings or canals are seen most clearly near the surface of the coenenchyma; they take a sinuous or zigzag course in the

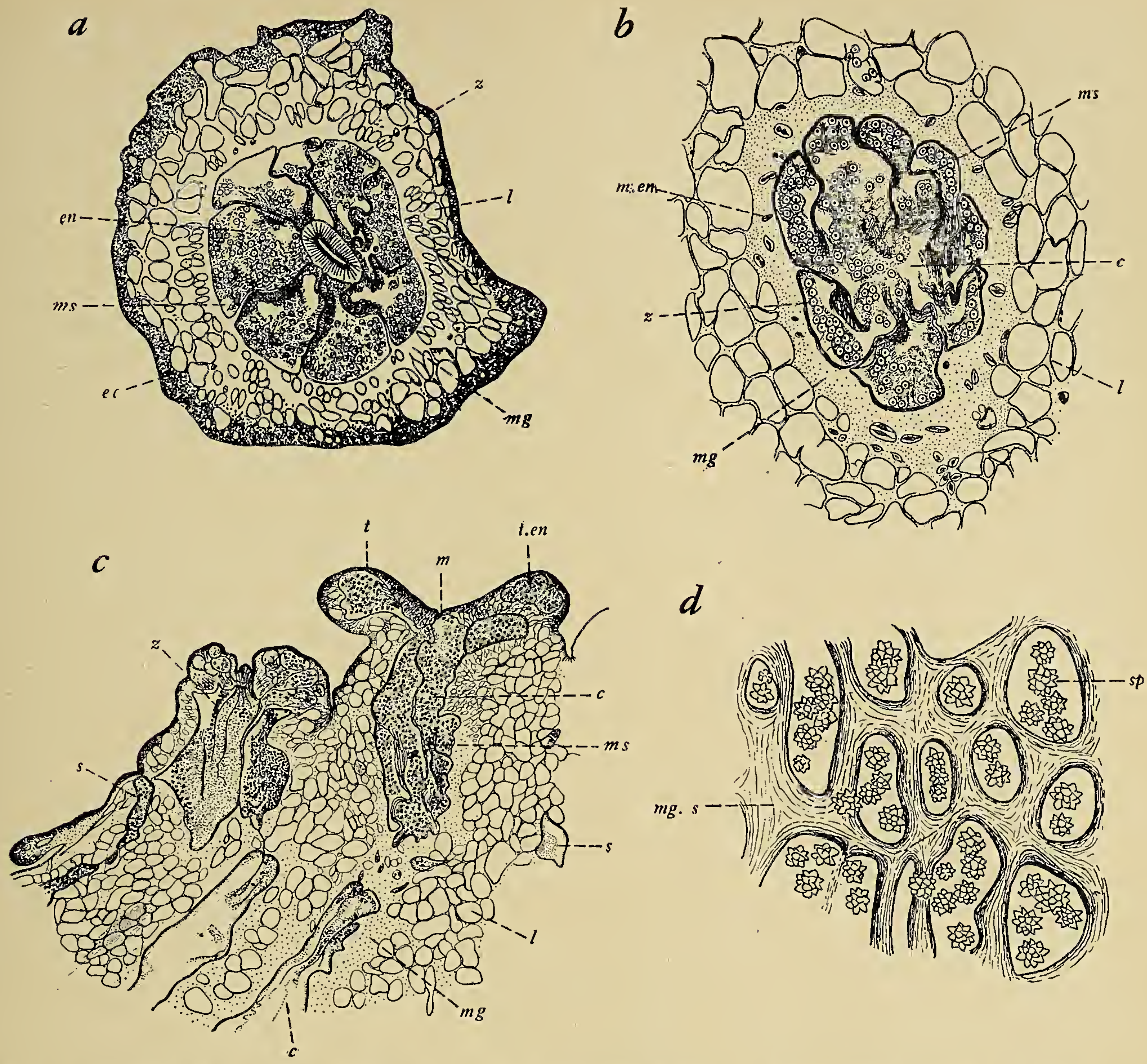

FIG. 2. *Asterospicularia laurae* n. gen. et n. sp.: *a*, transverse section of stomodaeal portion of polyp, ×85; *b*, transverse section of lower portion of polyp, ×135; *c*, longitudinal section of a part of coenenchyma with two polyps, ×50; *d*, superficial view of a part of coenenchyma, showing the arrangement of spicules, ×70. *a–c* from decalcified preparations and *d* from perfect specimen. (*c* coelenteron, *ec* ectoderm, *en* endoderm, *l* lacuna containing spicules, namely spicular cavity, *m* mouth, *mg* compact portion of mesogloea, *mg.s* mesogloeal partition between spicular cavities, *m.en* mesogloeal cell of endodermal origin, *ms* mesentery, *s* solenia, *t* tentacle, *t.en* tentacular branch of coelenteron, *z* zooxanthella.)

mesogloea between the spicular cavities and then communicate with the neighboring cavities. Usually they have no lumen, but contain granular endodermal cells and zooxanthellae similar to those found in the coelentera (Fig. 2*c*).

Zooxanthellae occur only in the endoderm, never in the ectoderm or in the mesogloea. They are most numerous in the tentacles and in the upper part of the coelentera between the mesenteries and solenia; they are found only sparsely in the deeper part. They are spherical and vary in diameter from 6 to 8μ, the majority being 7.5μ.

The stellate spicules, as mentioned above, occur only in the sharply circumscribed, rounded cavities of the honeycombed mesogloea. The number of spicules contained in each cavity varies greatly according to the size of the cavity. The mesogloeal partitions between these cavities, which are very thin and compact and which appear to be a homogeneous fibrous structure, contain no spicules at all (Fig. 2*d*).

REMARKS ON SYSTEMATIC POSITION

Before entering into a consideration of the systematic position of this remarkable alcyonarian, some historical remarks may not be amiss. It is interesting to note that there is good evidence that another specimen evidently referable to this form had been obtained and observed by two famous English workers on Alcyonaria 20 years ago. In an elaborate work on the alcyonarians collected by the Siboga Expedition (*Siboga-Expeditie*, XIIId, p. 219, pl. 21, fig. 8) issued in 1931, we find a short account by Sir Arthur J. Thomson and Miss Laura M. I. Dean (Mrs. L. M. I. Macfadyen) entitled, "Deceptive Fragments," as follows:

> Stat. 60. Haingsisi Reef. 1 Ex.
> Stat. 81. Sebangkatan, Borneo-Bank. 34M. Coral bottom and Lithothamnion. Several Ex.
>
> Several badly preserved fragments of a pronounced white colour, with a marked suggestion of shrunken *Alcyonium* or *Lobularia* colonies, and showing on some of the zooids eight tentacles (non-pinnate however), turn out to be compound Tunicates, not far removed from *Sarcodidemnoides*. The calcareous spicules, minute tuberculate spherules, are more refractive than those of Alcyonarians; as an instance of deceptive convergence we have figured a few.

This account and a sketch of spicules show quite decidedly that the so-called "deceptive fragment" was none other than a specimen of the present alcyonarian. It is small wonder that both authorities took it for a didemnid-like tunicate because of the peculiar shape of its spicules alone. In the group Alcyonaria, the form and arrangement of spicules constitute one of the most important characters of the genera and, often, of the species. They are usually represented by discs, rods, clubs, spindles, or capstans, all of which are simple, warty, or more complicatedly tuberculated or ramified. However, such distinctly star-shaped spicules resembling those in certain sponges and tunicates, as found in this *Asterospicularia*, are yet unknown in the Alcyonaria. In this respect, Hickson's opinion (1930: 230) that "The characters of the spicules are of great value in distinguishing the genera, and often of the species, but they are of little value in the division of the Alcyonaria into groups of higher rank," is not applicable to this case.

In this alcyonarian, the spicules are remarkably constant in form and size and are uniformly distributed in the mesogloea, except on the oral side of the tentacles, and do not form any special polyp armature. In this respect this species resembles more closely members of the Xeniidae than of any other family. However, it may be distinguished from the Xeniidae by the presence of spicules in the mesogloeal lacunae; for in the Xeniidae the spicules are confined to the ectodermal layer. The mesogloeal lacunae containing spicules are better developed than in the Alcyoniidae and Nephthyidae and are constant in form; moreover, the spicules in each lacuna are generally more than one in number. In the latter families, each lacuna is rather ill-defined and contains usually a single spicule almost similar to the outer contour of the lacuna.

In the mode of branching and in having numerous spicules scattered in the thick coenenchyma between the polyp cavities, this alcyonarian seems to be more closely related to the family Alcyoniidae and the genus *Capnella* of the Nephthyidae than to any other form, except that the mesogloea of the coenenchyma shows an unusually honeycombed structure as in that of the polyp body.

The coelenteron, which has scattered endodermal cells and zooxanthellae without forming any ordinary epithelial lining, seems to be rather peculiar. But the endodermal canal system seems to differ little from that of the Alcyoniidae.

The absence of pinnules in the tentacles is also characteristic, and is certainly noteworthy, since the pinnate tentacle is one of the most important diagnostic characters of the group Alcyonaria, with the one exception of *Acrossota liposclera* (cf. Kükenthal, 1924). A remarkable pinnule-less alcyonarian, first recorded from Amboina by Burchardt (1898) as *Clavularia amboinensis*, was, in fact, an *Anthelia*. A second species, *Acrossota liposclera* described by Bourne (1914) as a new genus and new species, is, according to Thomson and Dean (1931), probably identical with Burchardt's *C. amboinensis*. In some alcyonarians —e.g., *Pachyclavularia erecta*, *Cespitularia stolonifera*, and others—examined by early authors and also by me, there are often found some highly contracted tentacles seemingly devoid of pinnules (cf. Thomson and Dean 1931: 20; Gohar 1940*a*: 5). It is possible that this condition is the result of bad preservation and contraction. The present *Asterospicularia* is obviously different from *Pachyclavularia*, *Cespitularia*, and other xeniid specimens, as mentioned above.

Taking into consideration all of the unique features of the specimen described above, it seems certain that it represents a new type of alcyonarian which shows a close affinity with the Alcyoniidae as well as with the Nephthyidae; but it cannot to be included in either family. Moreover, it also demands a modification of the definition of the group Alcyonaria or Octocorallia generally used in all handbooks and textbooks of zoology. Thus I think it necessary to erect a separate family, ASTEROSPICULARIIDAE, for this specialized form, which I propose to call *Asterospicularia laurae*,[2] n. gen. et n. sp.

The characteristics of the new family may be put down as follows:

ASTEROSPICULARIIDAE n. fam.

Fleshy Alcyonaria of bushy growth type, with mushroom-like, polyp-bearing lobes and a sterile common stalk. Polyps of similar size non-retractile and protected by uniform spiculation continued from coenenchyma. Coenenchyma rather thick between polyp cavities and formed of highly honeycombed mesogloea which contains one or more stellate spicules in each cavity. Polyp cavities united together by means of well-developed endodermal cell-strings or solenia running in mesogloeal partitions between spicular cavities. No dimorphism of polyps. Tentacles highly contractile, with no trace of pinnules.

TYPE: *Asterospicularia laurae*, n. gen. et n. sp.

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[2] The specific name is chosen in honor of Mrs. Laura M. I. Macfadyen, who first recorded this form.

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Three New Species of *Aedes* from the Philippines (Diptera, Culicidae)[1]

KENNETH L. KNIGHT AND
WILLIAM B. HULL[2]

THIS IS THE TENTH PAPER of a series prepared by U. S. Naval personnel on mosquito collections made in the Philippine Islands under the auspices of Naval Medical Research Unit No. 2, and completes the description of the new *Aedes* species contained in that collection.

Aedes (Geoskusea) baisasi n. sp.

Fig. 1

ADULT:

MALE. Wing length approximately 2.5–3.0 mm. *Head:* Proboscis slightly longer than the fore femur, all dark-scaled. Palpus approximately 0.6–0.7 as long as the proboscis, exclusive of the labellum; dark; a very few stiff setae at the apices of the distal three segments and a few short hairs along the last segment. Vertex dorsally with broad dark scales, appearing paler along the eye margin, laterally with broad pale scales, usually a line of broad pale scales on the nape; an irregular line of dark upright-forked scales along the dorsal anterior margin of vertex, a patch of similar scales along the nape. *Thorax:* Scutal integument dark reddish-brown; clothed with narrow brown scales. Scutellum with a small patch of broad dark scales on the mid lobe, a very few narrow and broad dark scales on the lateral lobes. *Apn* bare of scales; *ppn* bare or with a few narrow and broadened dark scales dorsally, 2–4 posterior bristles, a few fine brownish hairs present ventrally. Propleuron bare. Sternopleuron with a dorsal patch of broad translucent brownish-white scales, these usually extending ventrally along the posterior margin, a considerable number of very fine short brownish hairs scattered over the remainder of the surface. Mesepimeron with a patch of broad translucent brownish-white scales, this patch being confluent ventrally with the dorsal hair tuft, a number of short brownish hairs present below the scale patch. Meteusternum (metanotum) with some fine pale hairs. Some of the pleural sclerites reddish-brown and markedly delimited by paler margins. *Legs:* Brown. The distal portion of the hind tibia and the basal portion of the first hind tarsal segment with outstanding narrow elongate scales on the inner surface. Fore tarsal claws unequal, large claw with one median and one basal tooth; small claw with a single subbasal tooth. Mid tarsal claws unequal, each with one subbasal tooth. Hind tarsal claws equal, simple. *Wings:* Brown-scaled. Halter stem pale, knob darker and with dusky scales. *Abdomen:* Tergites dark-scaled, lateral margin of I unscaled, a small baso-lateral pale scale patch on II–VII. Sternites pale-scaled basally, dark-scaled apically. *Genitalia:* Basal lobe of basistyle with sclerotized portion detached from basistyle tergally, many short thickened whip-like setae along mesal surface and with

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[1] The opinions or conclusions contained herein are those of the authors and are not to be construed as official or reflecting the views of the Navy Department or of the naval service at large. Manuscript received November 27, 1950.

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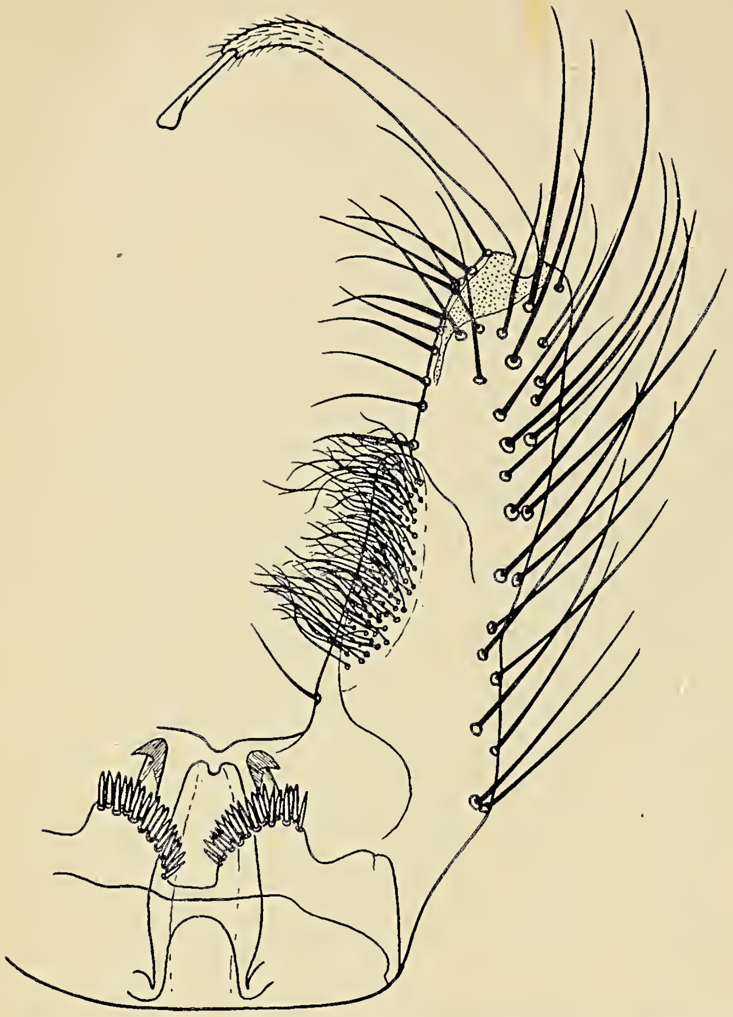

FIG. 1. *A.* (*Geoskusea*) *baisasi.* Tergal aspect of male genitalia.

much longer slender hairs on apex and for a variable distance basally. Ninth tergite lobes with 13–27 short stout peg-like spines and 1 or 2 bristle-like setae each.

FEMALE. Wing length approximately 3.0 mm. Largely similar to the male. Palpus approximately one-sixth to one-fifth as long as the proboscis. Tarsal claws equal, simple.

LARVA:

Unknown.

TYPES:

Holotype. Male (918.11), genitalia not separated, U.S.N.M. No. 59350, Iwahig Penal Colony, Palawan Island, Philippines, June 18, 1945 (J. L. Laffoon), collected as an adult from a crab hole at the edge of a mangrove swamp. *Paratypes.* Two males, 1 female, same data as for holotype; 11 males, 1 female, Pintanahon, Samar, April 13, 1945 (Laffoon); 1 male, Osmena, Samar, April 24, 1945 (Laffoon, Knight); 1 female, Zamboanga, Mindanao, September 12, 1945 (Laffoon, Johnson, Knight), taken from a light trap; 1 male, Zamboanga, Mindanao (Knight, Laffoon), September 15, 1945; 1 male, near Mangarin Bay, San Jose, Mindoro (Ross). All of the paratypes except the female from Zamboanga were collected as adults from the openings of crab holes in mangrove areas.

The holotype and a portion of the paratypes are deposited in the U. S. National Museum. The remainder of the paratypes are in the collections of the School of Hygiene and Public Health of the Johns Hopkins University, the California Academy of Sciences, and of the authors.

DISCUSSION:

Edwards (1932: 159) included *fimbripes* Edwards, *longiforceps* Edwards, and *tonsus* Edwards in the subgenus *Geoskusea.* In addition, he questioningly included *daliensis* (Taylor). Since that time, *daggyi* Stone and Bohart (1944:215) has also been added. In all of these species the male palpi are only about one-fourth as long as the proboscis.

In attempting to place the new species described above, we found that both it and the closely related *kabaenensis* Brug (1939:108) (formerly placed in *Skusea*) from the Celebes are similar to the known *Geoskusea* species in all important details except that the male palpi are approximately two-thirds as long as the proboscis. Since no other basic differences could be found, Edwards' (1932:159) definition of *Geoskusea* is hereby enlarged sufficiently to include these two species.

A. kabaenensis differs from *baisasi* mainly in possessing only 1–3 thick setae and 1–2 bristles on each lobe of the ninth tergite and in having the slender elongate hairs of the basal lobe of the basistyle confined to the apex of the lobe. The proboscis is described as being one and one-half times as long as the fore femur. Also, neither Brug's description nor the senior author's notes on the type of *kabaenensis*, which is in the British Museum, mention the occurrence of fine hairs on the mesepimeron below the scale patch. Unfortunately, no specimens of *bai-*

sasi were directly compared with the type.

It seems likely that when more material is available, *kabaenensis* and *baisasi* will prove to be members (subspecies) of a single polytypic species.

As pointed out above, *baisasi* and *kabaenensis* differ markedly from the other known *Geoskusea* species in having the male palpi approximately two-thirds as long as the proboscis. Also, conspicuous differences occur in the male genitalia.

This species is dedicated to Mr. F. E. Baisas, Malaria Control Section, Department of Health, Manila, Republic of the Philippines, who has contributed so materially to our knowledge of Philippine mosquitoes.

Aedes (Aedimorphus) mindoroensis n. sp.

Fig. 2

1929. *A.* (*Aed.*) *lowisi* Theo. Edwards, Not. Ent. 9:5.

1934. *Aëdes* (*Aëdimorphus*) sp. Edwards, footnote, in Barraud, Fauna Brit. Ind., Dipt. 5:250. Called attention to the fact that material named as *lowisi* by Edwards (1929:5) in actuality represents another species.

ADULT:

MALE. *Head:* Proboscis coloration obliterated. Palpi longer than the proboscis by slightly more than the length of the apical segment; dark; segments IV–V down-tilted, numerous long hairs arising apically and all along IV and V. Vertex with a narrow area of narrow pale scales along the dorsal portion of the eye margins; remainder of vertex with broad yellowish-white scales; brown upright-forked scales over the whole dorsum. *Thorax:* Scutal integument brown; badly rubbed, with some small narrow brown scales, marked on either side with at least two small clusters of yellow scales, one on the anterior margin and the other on a line with the first and on a level with the scutal angle. Scutellar lobes covered with broad silvery-white scales. *Apn* with a few broad silvery scales; *ppn* bare. Propleuron, upper sternopleuron, lower posterior sternopleuron, and upper mesepimeron each with a small patch of broad silvery-white scales; a few narrow yellowish scales on the subspiracular area. *Legs:* Femora and tibiae each with an apical patch of silvery-white scales anteriorly. Fore and mid tarsi dark, hind tarsal segments II–V missing but a narrow area of apical pale scales on I. *Wings:* Dark-scaled. A spot of silvery-white scales at the base of the costal vein. Halter knob with dusky scales. *Abdomen:* Tergite I with a lateral band of silvery-white scales; III–VI with basal bands of white scales, VII–VIII removed with genitalia and scale coloration lost. Sternites with brownish-yellow scales basally, brown scales apically. *Genitalia:* Basistyle without lobes; tergal surface with numerous very small setae, these extending laterad to the large lateral setae; sternal surface with a regular longitudinal row of stout long hairs near to mesal margin. Dististyle distinctively shaped as figured. Ninth tergite slightly concave medially.

FEMALE. Differs from the male mainly as follows: Proboscis pale beneath from near base to shortly beyond middle. Vertex with

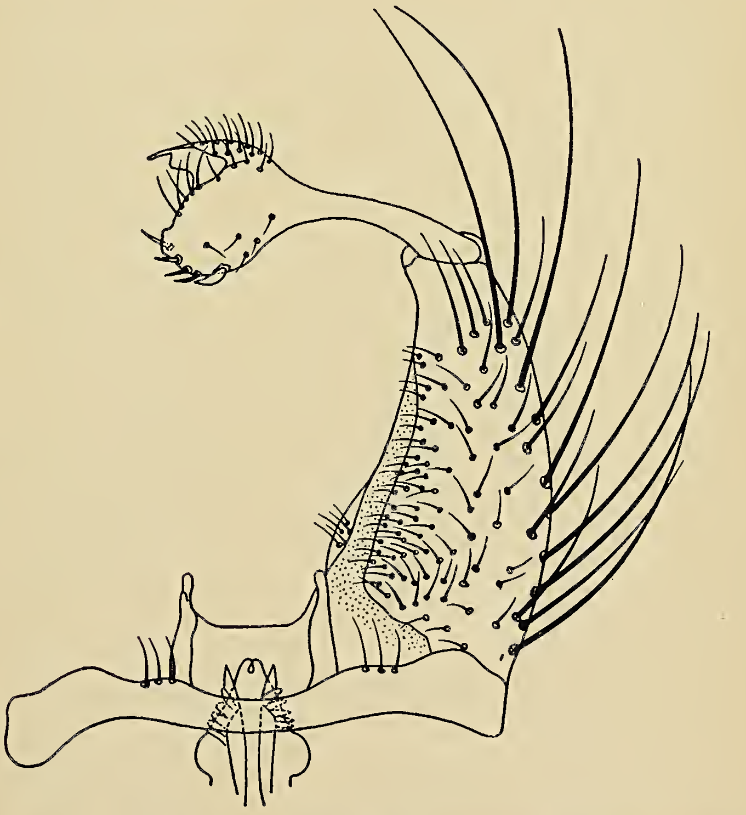

FIG. 2. *A.* (*Aedimorphus*) *mindoroensis*. Tergal aspect of male genitalia.

dorsum narrow-scaled, a median anterior diamond-shaped group of these dusky, the remainder golden; the lateral broad-scaled area creamy-yellow except for a dark patch at the dorsal margin and sometimes one on a level with *apn*. Scutum with yellow scales scattered over whole surface, in addition conspicuous aggregations of these scales occurring along anterior border, on the anterolateral area, above the wing base, and on the prescutellar area. *Apn* with a few narrow yellowish scales; *ppn* with a few dark narrow scales dorsally. Subspiracular area with a few dusky hairs. Fore tarsus with a few pale basal scales on III, with pale yellowish scales basally and apically on IV, V all pale yellowish. Mid and hind tarsi with narrow basal pale yellowish bands on II–IV, similar apical bands on I–IV, V all pale yellowish. Tergites with a baso-lateral patch of silvery-white scales, the basal bands (which are variable in occurrence and width) either separate from these, or only narrowly connected. Sternites white or creamy, with broad apical brown bands.

LARVA:

Unknown.

TYPES:

Holotype. Male, genitalia separated (B.M. 1929–599 from Helsingfors Mus.), Calapan (erroneously printed "Calopan" on label), Mindoro Island, Philippines, February 1, 1916 (Böttcher collection). *Paratypes.* Four females, same data as for holotype. No habitat data given.

The holotype and all the paratypes are deposited in the British Museum (Natural History), from which they were generously loaned to us by permission of the Trustees.

DISCUSSION:

Edwards (1932:166) divided the subgenus *Aedimorphus* into eight groups. Later, Knight and Hurlbut (1949:29) modified this classification by combining Groups D and C. The new species described above is a member of this combined group, Group C (*alboscutellatus-albocephalus*), a group with numerous species in both the Ethiopian and Oriental Regions (some intrusions into the Australasian and Palaearctic Regions from the latter). The Pacific species of *Aedimorphus* belonging to this group are as follows: *alboscutellatus* (Theobald), *argenteoscutellatus* Carter and Wijesundera, *culicinus* Edwards, *jamesi* (Edwards), *lowisi* (Theobald), *niveoscutellus* (Theobald), *oakleyi* Stone, *orbitae* Edwards, *pampangensis* (Ludlow), *punctifemore* (Ludlow), and *senyavinensis* Knight and Hurlbut.

A. mindoroensis is most closely related to *lowisi*, a species that is known only from the Andaman Islands and from Morotai, Moluccas (this latter locality is a new record in Rozeboom, Knight, and Laffoon coll.). Externally, the adult of *lowisi* is indistinguishable from that of *mindoroensis*. However, the male genitalia of *lowisi* differs in having the narrow basal portion of the dististyle equal to no more than half of the total length and in being evenly slender instead of being rather broadly tapered, in having the short tergal setae in a rather narrow band along the mesal margin, and in lacking any special arrangement of the sternal setae of the basistyle. Although the types of *lowisi* have been examined by the senior author, no drawing was made of the ninth tergite so that it is not known if any differences occur there. Because of the nature of the similarities between these species, it seems likely that a single polytypic species is concerned. However, much more material must become available before this can be definitely determined.

A. orbitae Edwards is similar to *mindoroensis* but differs in having the tarsal bands broader and whiter, in having a basal band on hind tarsal I, and in the markedly different form of the dististyle. *A. jamesi* (Edwards) is distinct in having the tarsal bands basal only and in details of the male genitalia.

All of the other Pacific species of Group C differ most notably in possessing all dark tarsi.

Aedes (?) *platylepidus* n. sp.

ADULT:

MALE. Unknown.

FEMALE. Wing length 2.5–3.0 mm. *Head:* Proboscis dark, approximately equal to fore femur in length, apical portion may be somewhat laterally compressed. Palpus one-fifth as long as proboscis, dark. Torus with broad silvery scales medially. Vertex broad-scaled, dorsum black, an anteromedian patch of silvery scales that extends laterally as a line along the eye margins, extreme margin of lateral aspect with an area of palish translucent scales, a clump of short black upright-forked scales on the nape. *Thorax:* Scutal integument dark brown, covered with overlapping broad plate-like scales, these scales blackish-brown and possessing a metallic luster, only a very small central portion of the prescutellar space free of scales; a few bristles on the anterior margin and a clump over the wing base, but no prescutellar, dorsocentral, or acrostichal bristles. Scutellum completely covered with the same type of broad dark scale that is found on the scutum, the line between the scutum and scutellum completely hidden by the overlapping of the scutal scaling. Postnotum bare. *Apn* (not particularly approximated dorsally) covered with overlapping broad black scales; *ppn* bare of scales, about 3 posterior bristles. Pleural integument dark; paratergite very broad; postspiracular area with only 2–3 small hairs, 1 propleural bristle, only about 1 sternopleural bristle (located posteromedially), only a few dorsal mesepimeral hairs (nearly covered by scale patch; was not possible to be completely sure that no lower mesepimeral bristle occurs). Following areas each with a patch of broad overlapping silvery scales: propleuron, the anterior area between the fore coxae (prosternum), all of the sternopleuron except a small anteroventral area, and all of the mesepimeron except along the posterior margin. Base of meron slightly above base of hind coxa. *Legs:* Coxae anteriorly covered with overlapping broad silvery scales, some dark scales on mid coxa. Fore and mid femora anteriorly dark except for a small pale basal area and narrow white apical spots (may be absent on fore femur), posteriorly dark except for a basal pale area; hind femur white, apical one-third black except for a narrow white apical ring. Tibiae black. Fore and mid tarsi black except for a small dorsobasal white spot on I; hind tarsal segment I with a white band on slightly less than basal one-fourth (incomplete mesally), II all dark (a few basal white scales present), III dorsally all white except for a narrow apical area (extending onto lateral surfaces), IV–V all dark. Tarsal claws equal, simple. *Wings:* Dark-scaled. Dorsally the convex veins with small broad scales, the concave veins with narrow scales. Squama fringed. Bases of anterior and posterior fork cells approximately even. Vein 6 reaching distinctly beyond base of fork of vein 5. Halter pale, knob dark-scaled. On a wing of one specimen a hair was observed near base of vein 1. *Abdomen:* Tergites black-scaled, lateral margin of I with a silvery-scaled band, II–VI with basolateral silvery-white spots and narrow dorsobasal silvery bands (connected to the spots) on III–VI. Sternites with white basal bands. Eighth segment completely withdrawn into the seventh.

LARVA:

Unknown.

TYPES:

Holotype. Female (810.8), Puerto Princesa, Palawan Island, Philippines, May 24, 1945 (J. L. Laffoon and D. R. Johnson), reared from a tree hole larval collection. *Paratypes*. One female (1608.2), Cape Melville, Balabac Island, Philippines, June 23, 1945 (D. R. Johnson), reared from a larva collected in a fallen coconut spathe. One female (1620.1), Cape Melville, Balabac, June 23, 1945 (J. L. Laffoon), reared from a larval collection from a log depression in a mangrove area.

The holotype and one paratype are deposited in the U. S. National Museum. The other paratype is in the collection of K. L. Knight.

DISCUSSION:

This species is strikingly different, on the basis of the broad plate-like dark (with metallic reflections) scutal and scutellar scales, from all other known Pacific *Aedes* species. In this respect, and in the absence of acrostichal, dorsocentral, and prescutellar bristles, it closely resembles another Philippine species, *Heizmannia scintillans* Ludlow. However, the generic characteristics of *Heizmannia* of having the anterior pronotal lobes (*apn*) closely approximated dorsally and the postnotum bearing a group of moderately long bristles apically are sufficient to exclude *platylepidus* from that genus. The American genus *Haemagogus* also has this type of scaling (and the same lack of scutal bristles) but, like *Heizmannia*, differs in having the anterior pronotal lobes closely approximated dorsally. *Aedes platylepidus* also shows a relationship with these two genera in having the base of the meron only slightly above the base of the hind coxa. In *Heizmannia* and *Haemagogus* these two bases are on a line, whereas in *Aedes* the base of the meron is (? always) well above the base of the hind coxa.

Although showing some resemblance to members of the genus *Armigeres*, this species differs in lacking prescutellar bristles, in the almost complete absence of sternopleural bristles, and in general habitus.

Lack of the male and larva of *platylepidus*, together with its rather aberrant characters, prevent the making of a definite decision at this time as to its subgeneric position in *Aedes*. In Edwards' (1932:131) subgeneric key to females, this species goes to *Macleaya*. This subgenus is based upon a single Australasian species, *tremulus* Theobald. However, *platylepidus* differs completely from this species in nearly all details of vertex, scutal, scutellar, and pleural scaling; and although no direct comparison of specimens has been possible, it seems quite unlikely that this species is at all closely related to *Macleaya*.

In general characteristics, this species seems to have much in common with the Ethiopian subgenus *Dunnius*. Perhaps the most striking correlation is the presence in this subgenus of several species that lack the scutal disc bristles, including the prescutellars, as does *platylepidus*. These are the only *Aedes* species recorded by Edwards (1932:174) as lacking these bristles. However, *platylepidus* is excluded from *Dunnius* by the simple female tarsal claws and in not having the proboscis distinctly longer than the fore femur.

Edwards (1932:179) questioningly (males unknown) places three Oriental species (*achaetae* Leicester, *discrepans* Edwards, and *tripunctatus* Theobald) in the genus *Haemagogus*, which on the basis of type descriptions seem to be similar to *platylepidus*. The type description of *discrepans* states that a postspiracular bristle is present, a condition which would seem to be sufficient to exclude this species at least from either *Haemagogus* or *Heizmannia*. An additional interesting fact is that *tripunctatus* has all simple tarsal claws in the female (Barraud, 1934:310).

Mr. P. F. Mattingly, British Museum (Natural History), has kindly compared a description of *platylepidus* with the types of *achaetae* and *discrepans* (*tripunctatus* not seen but apparently quite similar to *discrepans*). He reported that in general details they are much alike (particularly similar to *achaetae*). However, *discrepans* differs most notably in having both narrow and broad scutal scaling, thus resembling the subgenus *Dunnius*. Specifically *achaetae* differs in having at least the mid tarsal claws toothed and in lacking postspiracular bristles. He indicated that both *achaetae* and *platylepidus* show considerable general relationship with the genus *Heizmannia*.

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NOTES

The American Element in the Hawaiian Flora[1]

The geographic derivation of any flora is a matter of interest not only to taxonomists and phytogeographers but also to students of geology and geography and to those with a general intellectual curiosity as well. Reliable speculation on such a subject often provides useful keys to other related topics such as the geological history of an area, its paleoecology, the migrations of its peoples, and the phylogeny of special groups of plants.

The floras of oceanic islands seem to be particularly stimulating to such speculations, and that of the Hawaiian Islands has had its full share of theories. Hillebrand, Brown, Campbell, Skottsberg, and Copeland are among those who have expressed opinions. The latest such expression that I know of was presented by me, two years ago (in E. C. Zimmerman's *Insects of Hawaii* 1: 107–119, 1948). The outstanding characteristic of this collection of opinions is its diversity. Hillebrand and Brown, especially, recognized a large element of American affinity. Later writers have rather minimized this.

My own approach differed from that of most earlier writers in being an attempt to ascertain the number and derivation of the probable original successful colonists responsible for the present indigenous Hawaiian flora. The percentage of each element in the present flora was then determined on the basis of these original colonizations rather than of the total present flora. This, it was felt, would eliminate the disproportion introduced by such rapidly evolving groups as *Cyrtandra*, the Rubiaceae, the lobeliads, *Metrosideros*, etc. It is thought that there were about 407 such successful colonists.

The percentages of the floristic elements in the vascular flora, recognized on this basis, are as follows:

REGION	PERCENTAGE
Indo-Pacific	42.7
Austral	12.2
American	16.2
Boreal	3.1
Pantropic	15.4
Obscure	10.5

The figures for the seed plants and vascular cryptogams were originally published separately, but are here combined. For the American element the seed plant percentage is 18.3 and that of the pteridophytes, 11.9. There were possibly a total of 69 original successful immigrants from America, of which 51 were seed plants and 18 pteridophytes.

Now, let us look at some of the interesting features of this American element.

Of the total of 69 possible American introductions, 40, or about 58 per cent, have changed very little since their arrival. Twenty-one are identical or only varietally distinct from their American relatives. Nineteen are closely related species. Of the other 42 per cent, 19 species are clearly, though not closely, related to American plants; the remaining 10 may be regarded as questionable. I am on insecure ground when discussing certain of the larger fern genera where the Hawaiian species may be closer to American ones than I realize.

Of the total American component, only four genera, *Isodendrion*, *Nothocestrum*, *Psychotria*, and *Hesperomannia*, have given rise to any significant number of evolutionary off-

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[1] Paper read at Seventh International Botanical Congress, Stockholm, Sweden, July, 1950. Manuscript received September 28, 1950.

shoots that still survive, and none has produced a large number. Furthermore, all these genera are among the more doubtfully American of the lot.

There are only two strand species in the American element—*Lycium carolinianum* and *Jacquemontia sandwicensis. Chenopodium oahuense* grows at sea level as well as in dry uplands. Of course, some of the pantropic strand plants may be of American origin.

Of the total, only *Sapindus* and *Psychotria* have seeds too large to be easily distributed by wind.

There are about eight cases of probable bird dispersal—plants whose seeds logically might have stuck to birds' feet or feathers. Prominent among these is *Fragaria chiloensis*, which grows on sea beaches from Chile to Alaska and in the uplands of the island of Hawaii. Alaska is the summer home and Hawaii the winter home of the Pacific plovers and curlews. In addition to these, there are about eight other plants with fleshy fruits which may have been brought in birds' intestines, though this is less likely over such distances.

Human agencies cannot be absolutely excluded in about 10 cases, though the possibilities have been carefully weighed, and only about 2 of these 10 are regarded as at all likely. Those that seem really to have entered Hawaii by human introduction have been excluded as non-indigenous. One cannot positively exclude very early historical introduction for a few plants, such as *Hesperocnide* and *Daucus*, or prehistoric human transport for such as *Argemone;* but it is unlikely. The *Hesperocnide* is considered an endemic species and the *Argemone* an endemic variety of *Argemone alba*.

Gossypium tomentosum is a special case. Cytological investigations by Hutchinson, Stephens, and Silow have led them to the conclusion that this species and the two widespread cultivated American cottons form a closely related group derived by hybridization between an Asiatic cotton and a wild diploid American cotton. They think that this hybridization followed prehistoric human introduction of an Asiatic cotton into America (where it does not now persist), and that *Gossypium tomentosum* was then carried back to Polynesia and to Hawaii by Polynesian travelers.

There are several weaknesses inherent in this theory. Even supposing that the Polynesians had made such voyages, it seems scarcely likely that they would have selected for taking back the one perfectly useless cotton of the three, or that it would not have persisted elsewhere along the route in Polynesia. The fiber of *Gossypium tomentosum* is only a few millimeters long. The greatest cause for doubt, however, lies in Dr. Silow's statement (in conversation, 1949) that *Gossypium tomentosum* is closely related to the cultivated cottons. Morphologically, at least, this does not seem to be true. T. H. Kearney, long an authority on cottons, has told me that he regards it as closest to a wild species of the Galapagos Islands. I am well acquainted with *Gossypium tomentosum* and with both cultivated American cottons and find little similarity.

I suggest that *Gossypium tomentosum* be reexamined cytologically, using material about whose origin and identity there can be no doubt. It may be that there has been a confusion with the forms of *Gossypium barbadense* that have long been introduced and established in Hawaii.

To return to general considerations, it seems fairly safe to assume that identity or close relationship with American species indicates that isolation from them has not been of very long standing. The lack of extensive evolutionary differentiation suggests the same thing. It is realized, of course, that there may well be exceptions to these generalizations. But when almost 60 per cent of the presumed American stocks in the flora are identical with or very close to their American relatives, and when over 94 per cent have not given rise to any number of evolutionary progeny, and when the largest number of species and varieties in any one of the stocks is less than a dozen, and that in *Psychotria*, one of the rather questionably American members, one may draw certain conclusions with some confidence. It would seem safe, at least, to say that the American element, generally, is a comparatively late addition to the Hawaiian flora. It would be premature to speculate on the significance of this until all of the other elements of the flora have been examined in a comparable manner.—*F. R. Fosberg, Pacific Vegetation Project, Catholic University of America, Washington, D. C.*

News Notes

On March 9 and 10, 1951, about 130 of the leading scientists of Hawaii met in Honolulu at the invitation of the Hawaiian Academy of Science to discuss the status of scientific research in the Pacific and to make recommendations for further work.

At the initial general meeting, brief summaries were given of the research activities of various scientific organizations represented in Hawaii.

Dr. L. D. Baver, vice president of the Academy, directed the general session in the absence of the president, Dr. E. C. Auchter.

For purposes of discussing the problems of their particular interest, the scientists were organized into the following eleven committees which convened in meeting places provided by the Pineapple Research Institute and the neighboring University of Hawaii, Pacific Oceanic Fishery Investigations building of the U. S. Fish and Wildlife Service, and the Institute of Pacific Relations:

COMMITTEE	CHAIRMAN
Geology, Geophysics, and Hydrology	Doak C. Cox
Meteorology	W. A. Mordy for R. H. Simpson
Oceanography and Zoology	A. L. Tester
Entomology	C. E. Pemberton
Conservation	L. D. Baver
Museums in Pacific Research	E. H. Bryan, Jr.
Soil Survey and Land Classification	Z. C. Foster
Crop Improvement and Soil Management	J. L. Collins and J. H. Beaumont
Animal Improvement	Sam B. Nordfeldt
Anthropology and Social Sciences	Leonard D. Mason
Health and Nutrition	C. L. Wilbar

More than 150 recommendations were presented by these committees at the concluding general session and were adopted by the combined group with but slight modification. Most of these recommendations have specific application to Hawaii, but several are concerned with Micronesia and other Pacific island groups. Many should be of interest to committees preparing for the Eighth Pacific Science Congress. The results of the symposium will be published in the *Proceedings of the Hawaiian Academy of Science* following the annual meeting in May.

In planning and carrying out this symposium, generous help was given to the officers of the Hawaiian Academy of Science by the Secretariat of the Pacific Science Council.

If this symposium accomplished no more than the convening of so many of the scientists of Hawaii, to help them discuss their mutual interests and problems, it will have been worth while; but it is believed that putting on record such a summary of scientific needs and goals may do much to stimulate scientific work in the Pacific.—*E. H. Bryan, Jr., Secretary, Hawaiian Academy of Science.*

GARNIER, B. S., Ed. *New Zealand Weather and Climate.* 154 pp., 14 figs. Misc. Series No. 1, New Zealand Geographical Society, Auckland, New Zealand.

As a series of essays on related topics rather than an organized work progressing through the subjects from start to finish, this booklet presents some very concise and informative material on the New Zealand climate.

All the papers are in readable, descriptive terms and cover a history of the New Zealand Weather Service from its beginning in 1859 to the present day, a description of the geographical and seasonal variations of New Zealand climate, and a classification of these climates according to the Thornthwaite system. The compilation includes several papers which have appeared elsewhere as well as several new discussions to make up the first in a series of special publications by the newly formed New Zealand Geographical Society. Accompanying data and figures give average monthly and annual rainfall and temperature figures for principal weather stations and mean annual rainfall maps for a 35-year period of record. Other figures include maps of rainfall variability and charts of rainfall, hail and fog frequency, prevailing wind, temperatures, etc., for related stations.

Of primary interest to meteorologists will be the discussion of forecasting New Zealand weather by Ian M. Watts. The author makes use of an unusual illustrative technique in describing the weather and cloud distributions associated with the various types of meteorological disturbances passing through the country. These are in the form of photographs of relief maps over which tufts of cotton representing clouds have been placed. These photographs give the reader an excellent picture of an area with which he is likely to be unfamiliar, thus allowing him to follow the discussion readily.

Although the editor makes apologies for publishing a book on "such a small and sparsely populated country as New Zealand," this book represents a type of information which should be available for a great many more areas of the world. It is happy to note in this respect that this is only the first of a series of publications designed to provide an outlet for geographical research on the New Zealand Area—W. A. Mordy.

TAYLOR, WILLIAM RANDOLPH. *Plants of Bikini and Other Northern Marshall Islands.* University of Michigan Studies, Scientific Series, Vol. 18: xv+227 pp., color frontispiece, 79 plates. University of Michigan Press, Ann Arbor, 1950. $5.50.

Dr. Taylor's attractive book is the account of his plant collections made on "Operation Crossroads" preliminary to the atomic bombing of Bikini Atoll. Excluded are the phytoplankton and the bacteria; included are 181 algae, 12 fungi, 6 lichens, 1 moss, and 56 flowering plants.

The introductory chapters include: previous botanical exploration of the Marshall Islands; descriptions of the atolls and their marine flora; characteristics of the land flora; and detailed botanical features of the atolls studied—Rongerik, Rongelap, Bikini, and Eniwetok.

The remaining text consists of a systematic account of the plant species. For Cryptogams there is given the class name, the family name, the generic name, its authority and date, the binomial and authority, a description (often full and detailed), a discussion of the habitat and special features or relationships, and a citation of collections by islands. Synonyms are conspicuously lacking, as is the reference to the place of publication of the accepted name of the species or taxon. The full Latin diagnoses of the new plants are in an appendix.

For the Spermatophyta the treatment is similar. It is possible from clear statements or implications to calculate that the higher plants consist of 40 indigenous, 8 adventive, 5 crop, and 3 cultivated ornamental plants. The descriptions are full and the localities definite. After each generic heading is given the authority, but the date (which was given in the Cryptogams) is here omitted.

In the nomenclature there are numerous inadequacies. If the pre-Linnaean author Plumier is to be credited with the genus *Pisonia* (p. 177), as was done by Linnaeus himself, it should be written Plumier ex Linnaeus, and so, too, should the same authority be credited for *Hernandia* (p. 181), *Suriana* (p. 183), *Triumfetta* (p. 186), *Cordia* (p. 194), and *Ximenia* (p. 198). Similarly the full author citation for the following genera should be: *Eragrostis* (p. 164) Palisot de

Beauvois (not Beauvais), *Setaria* (p. 167) Palisot de Beauvois, *Clerodendrum* (not *Clerodendron*) (p. 196) Burman ex Linnaeus, *Morinda* (p. 200) Vaillant ex Linnaeus. Also *Boerhaavia* (p. 176) should be *Boerhavia* (the original and valid spelling), and *Allophyllus* (p. 185) should read *Allophylus*.

In the authorities for the species, there are also inaccuracies. The several species credited to Forster on pages 164, 168, 175, 176, 186 should be credited to Forster filius (J. G. A. Forster). *Tacca leontopetaloides* was not authored by (Linnaeus) Merrill, but by (Linnaeus) O. Kuntze. *Sida fallax* (p. 187) was not published by Walpole, but by Walpers.

From the earliest voyages to the present, all explorers have admired the completeness of knowledge of the larger plants by the native Pacific peoples. Ethnobotanical information as to vernacular names and the uses of the plants is almost wholly lacking in this book, except for a few notes on *Cocos* and *Tacca*. This is regrettable since the people of Bikini have now been removed and no record was made of their local plant lore. The omission is probably due to "military restrictions to prevent interference with native residents" (p. 19).

Taylor does not explain the kind of book or the reading public he had in mind. It is clearly not a book for popular reading, but is a technical botanical book. It does not seem to be provided for the specialists who know much of the Pacific flora and have at hand the basic literature and large Pacific plant collections, since for these very few individuals, there would be no point in printing descriptions of all the previously known species. Hence, the book appears to have been written as a combined technical and semi-popular one, for the many naturalists interested in the Pacific and for the officials or travelers who visit the general area. To these the description and detailed distribution of each species will be of value. But, for those species not illustrated, the student will find identification unnecessarily arduous, since there are no general keys, and none at all except for the genera *Caulerpa*, *Halimeda*, and *Liagora*.

Taylor knew of the details of the vegetation of the southern Marshall Islands only from the accounts by Volkens and by Koidzumi of the single atoll Jaluit. From this basis he compares (p. 3) the flora of the two extremes and concludes that the southern atolls are notable by the "apparent absence of *Suriana*, *Fimbristylis*, *Tacca*, *Pisonia*, *Boerhaavia*, *Dodonaea*, *Clerodendron*, *Ochrosia*, and other genera." We now have collections verifying the occurrence of *Dodonaea* on Wotje, and all the other genera listed by Taylor as missing we now know on several of the southern atolls; actually all but one of the remainder occur on Jaluit, and all but two on the southernmost atoll of the group, Ebon. Hence, the comparison, quoted above, was premature and not a true one.

Nevertheless, Taylor's *Plants of Bikini* is a welcome addition to the accounts of the Pacific flora, giving excellent topographic and vegetational accounts, a good summary of the terrestrial flora, and an original and detailed systematic presentation of the lower plants, particularly the marine algae. It is worth the price.—Harold St. John.

Japanese Journal of Ichthyology (*Nihon Uo Zasshi*), published by the Japanese Society of Ichthyologists (Uo no Kai), Zoological Institute, Faculty of Science, Tokyo University, Hongo, Tokyo, Japan.

This is a new Japanese journal, the first number of which was released on August 20, 1950. The Journal will appear bimonthly, and will present scientific articles, reviews, comments, editorial notes, and news items. Most of the articles in the first issue are written in Japanese, with résumés in English; a few articles are written entirely in English. The chief editors are T. Abe, H. Arai, N. Y. Kawamoto, Y. Okada, and K. Suyehiro.

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——— 1920*b.* Cerotrioza (Psyllidae, Homoptera). *Hawaii. Ent. Soc., Proc.* 4 (2): 374–375.

ROCK, JOSEPH F. 1916. The sandalwoods of Hawaii; a revision of the Hawaiian species of the genus *Santalum. Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry Bot. Bul.* 3: 1–43, 13 pls.

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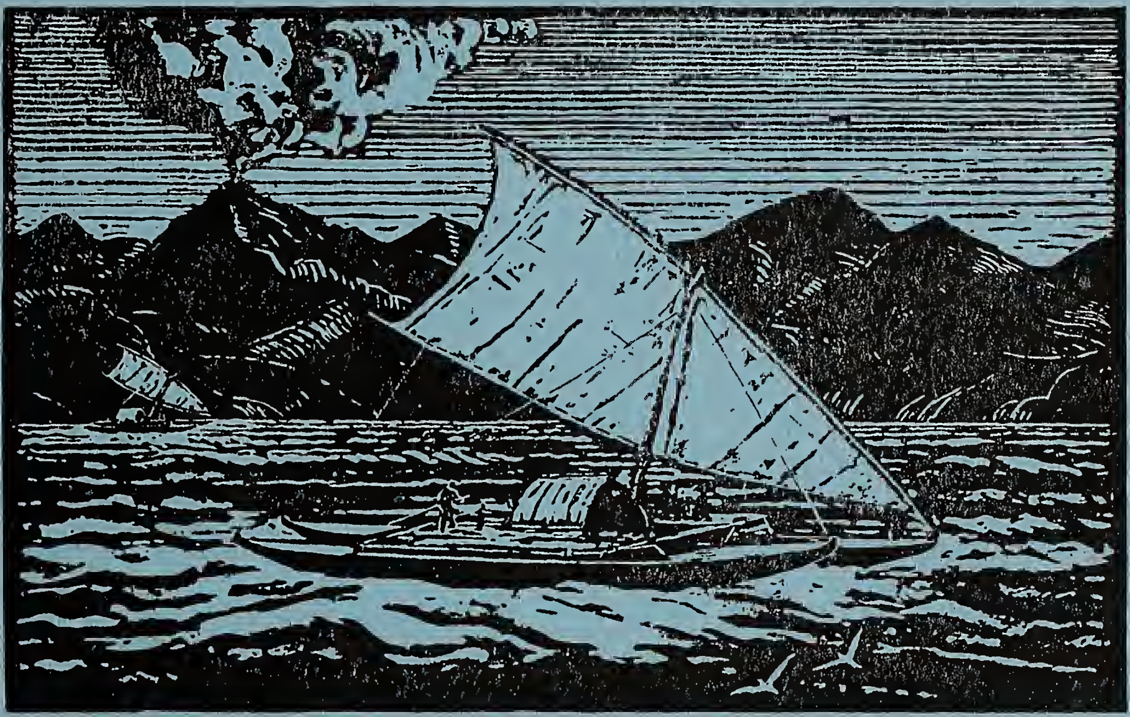

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The *Aedes* Mosquitoes of the Philippine Islands[1]

I. Keys to Species. Subgenera *Mucidus, Ochlerotatus,* and *Finlaya* (Diptera, Culicidae)

KENNETH L. KNIGHT AND WILLIAM B. HULL[2]

INTRODUCTION

EXTENSIVE COLLECTIONS of mosquitoes made in the Philippines during the last war have resulted in a great increase in our knowledge of the culicid fauna of that island group. This has been particularly true for the genus *Aedes*. In 1945 Bohart listed 34 *Aedes* species for the Philippines, of which only 6 were known in the larval stage from Philippine specimens. The present series of three papers, of which this is the first part, treats 74 named species and subspecies, and Philippine larval specimens were seen for 56 of these.

Material Used

This study has been based primarily upon the collection made from April to October, 1945, by a branch unit of U. S. Naval Medical Research Unit No. 2 (NAMRU–2) on the islands of Luzon, Leyte, Samar, Palawan, Balabac, Culion, Busuanga, Mindanao, Basilan, and Jolo. This collection, consisting very largely of adults associated with their larval and pupal skins, was gathered by L. E. Rozeboom, K. L. Knight, J. L. Laffoon, and D. R. Johnson. In addition, numerous non-technical service personnel contributed considerably to the task.

The second largest source of material studied was the collection of the U. S. National Museum, which is particularly rich in Philippine type specimens. Before the last war, the Philippine mosquito collection of the National Museum consisted principally of material collected by the U. S. military occupation forces following the Spanish-American War and contributed by them through C. S. Ludlow. The only other important source during this period was the collecting of C. S. Banks. He sent excellent material of many species to both the British Museum and the National Museum, but retained most of the types in Manila, where they were all destroyed in the seizure of that city by the Allied forces in World War II. Following World War II, several collections of mosquitoes from the Philippines were deposited in the National Museum. Important among these contributions are those of H. Hoogstraal, K. V. Krombein, S. E. Shields, J. H. Paullus, J. T. Medler, and A. B. Gurney.

Additional important collections, all made during World War II, that were drawn upon for this paper are those of the Academy of Natural Sciences of Philadelphia, collected by H. R. Roberts; the California Academy of Sciences, collected by E. S. Ross; and Cornell University, collected by J. G. Franclemont. Representative portions of the *Aedes* collection of the Philippine Bureau of Health (made by F. E. Baisas and his associates) were also drawn upon.

A number of the types of Philippine species occur in the British Museum and these were all extensively studied and compared by the senior author in 1946.

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[1] The opinions or conclusions contained herein are those of the authors and are not to be construed as official or reflecting the views of the Navy Department or of the naval service at large. Manuscript received November 27, 1950.

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Explanations

In the period from 1946 to 1951, the following series of 10 papers was published on Philippine *Aedes* species (48 in all) contained in the NAMRU-2 collection: Knight and Rozeboom (1946), Laffoon (1946), Knight (1946), Knight and Laffoon (1946), Rozeboom (1946), Knight (1947, 1947*a*, 1947*b*, 1948), and Knight and Hull (1951). Because of the limitations of space and to avoid extensive duplication, the descriptive and biological sections and the illustrations for all the species treated in the above series of papers are omitted from this present work.

The specimens in the NAMRU–2 collection of the remaining Philippine *Aedes* species are here reported for the first time. The bulk of the collection used for the previously published treatments is deposited in the National Museum and is listed in the distribution section for each species following the heading, U.S.N.M. The published records of this material are not included under "Literature Record" of distribution, except for the subgenus *Aedes*. The material not previously published is given after the heading, R.K.L. The names of collectors and the number of specimens included have been omitted from those records which have been previously published. In a few other cases, the number of included specimens has been omitted because it is no longer available.

In general, the morphological descriptive terminology employed here is that used and explained by Carpenter, Middlekauff, and Chamberlain (1946). However, several departures from this terminology have been made. Chief among these are the following: the treatment of the paratergite as a pleural sclerite instead of a mesonotal structure, where it morphologically belongs (this has been done for convenience since it is more easily noted when an examination of the pleural sclerites is being made); the use of the term meteusternum for the area designated by them as the metameron; the use of Marshall's (1938: 40) larval head hair numerical nomenclature; and the listing of the larval eighth abdominal segment hairs in dorsal-ventral order with Arabic numerals.

Subgeneric synonyms are given only in those cases where they were first applied to a species that occurs in the Philippines. The subgeneric descriptions apply specifically only to Philippine species.

Unless otherwise stated, the data included under bionomics are those gathered in the formulation of the NAMRU–2 collection.

The figures in this paper were not drawn to scale. Illustrations marked with the initials WBH were made by the junior author.

A dagger (†) in the synonymy sections denotes types that have been examined by us.

The following abbreviations are used in the descriptions. Adult: *apn*—anterior pronotal lobe; *ppn*—posterior pronotal lobe. Larva: *isc*—inner or upper caudal hair of the anal segment; *osc*—outer or lower caudal hair of anal segment; *lh*—lateral hair on anal plate.

The following abbreviations are used in the species distribution sections to denote the present locations of specimens examined. A.N.S.P.—Academy of Natural Sciences of Philadelphia; C.A.S.—California Academy of Sciences; U.S.N.M.—U. S. National Museum; B.M.—British Museum (Natural History); C.C.—Cornell University; R.K.L.—specimens from the collection of Naval Medical Research Unit No. 2 on which nothing has been previously published and which are now deposited in the U. S. National Museum, the Johns Hopkins University, the Knight collection, the California Academy of Sciences, and the British Museum.

To obtain uniformity in the listing of the distribution of each species, the *Gazetteer to Maps of the Philippine Islands*, second edition, 1944, published by the Army Map Service, Corps of Engineers, U. S. War Department, has been used for the spelling of all place names. The islands of Luzon, Cebu, Panay, Negros, and Mindanao are divided into provinces, and in nearly every case distribu-

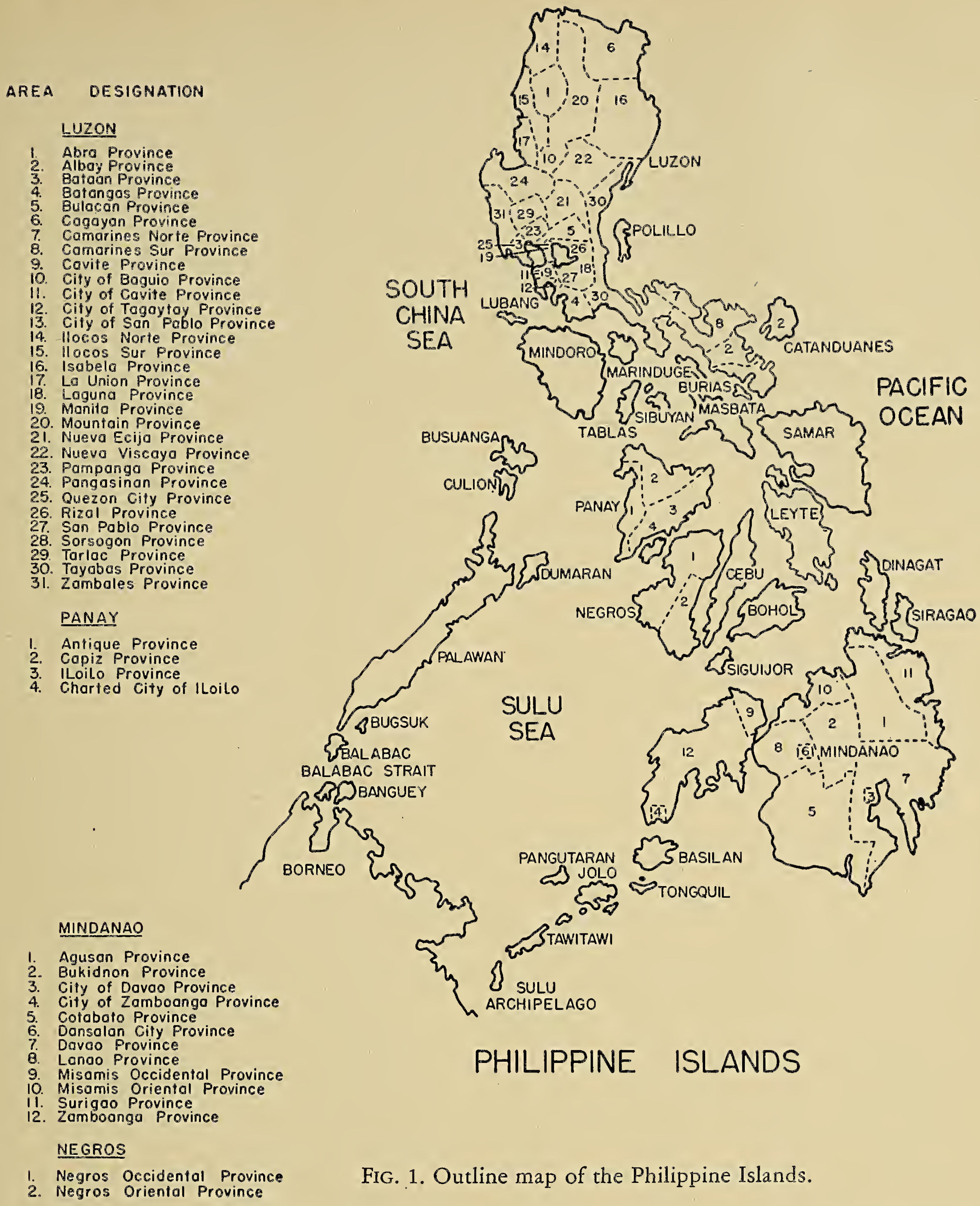

FIG. 1. Outline map of the Philippine Islands.

tion records from these islands include the name of the province.

It will be noted that this work, in conformity with American usage, omits the diaeresis from the word *Aedes*. This policy has been followed on the basis that since Meigen (1818:13) did not use the diaeresis in his original citation of the name it is not mandatory for subsequent users to employ it. Nor is it mandatory to follow a subsequent correction established on the basis of a supposed *lapsus calami*. It is true that in the index of the book containing the original reference to *Aedes* (p. 325) the first two letters are written as a diphthong, but it is quite open to question that Meigen prepared the index. Following the policy described above, the diaeresis has also been omitted from *Aedimorphus*, but has been used with *Cancraëdes*.

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KEYS TO THE PHILIPPINE SPECIES OF *Aedes*

Adult Key

1. Tarsi all dark...................... 2
   At least the hind tarsi with pale markings........................... 30
2. Scutellar scales narrow............. 3
   Scutellar scales broad, or mostly so.. 17
3. Vertex dorsum, scutum, and scutellum with conspicuous yellow scaling........................ 4
   Vertex dorsum, scutum, and scutellum largely dark-scaled, not with yellow scaling (*Aedes*)........... 5
4. Scutum with a broad area of yellow scales along lateral margin, central portion dark-scaled; wing with pale scaling along vein 1 to junction with stem of vein 2, on vein 5, and, in female, also on Sc........................ (*Banksinella*) *lineatopennis*
   Scutum with narrow longitudinal medial and lateral lines of yellow scaling; wing dark-scaled..................... (*?Aedimorphus*) *ostentatio*
5. Abdominal tergites II–VIII always with some white or yellowish baso-lateral markings, sometimes produced onto dorsum or sometimes reduced to only a few scales; (hind claws simple)................... 6
   Abdominal tergites II–VIII entirely brown (in *dux* sometimes with lateral border grayish or sometimes with an indefinite baso-lateral patch of paler brown scales on last few only); (mesepimeron never with more than 4 hairs behind scale patch, none below; about 5–10 small upright-forked scales on nape on either side of mid-line; about 10–12 verticillate bristles on most antennal segments of male)...... 15
6. Anterior median portion of sternopleuron with 6 or more fine hairs; (sternites almost entirely white).. 7
   Anterior median portion of sternopleuron bare of hairs or with only 1–2 (rarely up to about 8 very small hairs in *butleri* but this species with a considerable portion of the sternites brown-scaled and the scutal integument blackish-brown)...... 9
7. Male ninth tergite with a very large median Y-shaped process about as long as basistyle, each branch with an additional hairy branch on its sternal surface; female terminalia with atrial hairs confined to median area, preatrial plates not united..................... (*Aedes*) *macrodixoa*
   Male ninth tergite without such a process; female terminalia with atrial hairs not confined to median area and preatrial plates united for greater part of their length (female of *nubicolus* unknown)............. 8
8. Basistyle with a group of about 8–9 stout spines apically on the inner sternal margin; paraproct short; two very long processes arising near apex of basistyle, one with 3–4 stout spines near tip.......... (*Aedes*) *uncus*
   Inner sternal margin of basistyle without a group of stout spines; paraproct longer than basistyle; a broad

process near apex of basistyle with a row of about 4 heavy spines apically................(*Aedes*) *nubicolus*

9. Meteusternum with numerous fine hairs; basistyle with a group of about 8 stout spines on the inner sternal margin near the base; (male fore and mid legs with claws unequal, the larger ones uniserrate, the smaller simple).............. 10
   Meteusternum without hairs; basistyle without such a group of spines........................ 12

10. Apico-tergal prolongation of basistyle very wide, its 2 distal forks about equal in length; only 2 other long apical processes, sometimes a more sternal short spine also visible..................(*Aedes*) *adustus*[3]
   Apico-tergal prolongation of basistyle otherwise; three other long apical or subapical processes present.... 11

11. Apico-tergal prolongation of basistyle very wide...........(*Aedes*) *johnsoni*[3]
   Apico-tergal prolongation of basistyle much narrower.....(*Aedes*) *margarsen*[3]

12. Mesepimeron with at least 2 hairs below scale patch, usually more numerous...................... 13
   Mesepimeron with a number of bristles along upper margin but with no hairs ventral to scale patch and never more than 3–4 behind it.... 14

13. Upper sternopleural scale patch usually extending to anterior median angle of sclerite; abdominal sternites II–VII with a wide basal white band, covering at least basal one-half of each segment; male with claws of fore and mid legs equal and toothed, and dististyle simple; female with postatrial sclerite not trilobed.... ....(*Aedes*) *panayensis*
   Upper sternopleural scale patch never extending to the anterior median angle of sclerite; sternites entirely dark brown or with some white scales on basal one-third; male with claws of fore leg unequal, toothed, claws of mid leg unequal, simple, and dististyle forked; female with postatrial sclerite trilobed........ ....(*Aedes*) *butleri*

14. Scutal integument dark reddish-brown; sternites II–VII with about basal two-thirds of each segment white; male with smaller claws of fore and mid legs each with a small tooth, basistyle with a large patch of flat white scales laterally, and the paraproct forked beyond the middle; female without a large round dark preatrial plate in addition to the paired preatrial plates........ ....(*Aedes*) *campylostylus*
   Scutal integument blackish-brown; sternites II–VII brown; male with smaller claws of fore and mid legs simple, basistyle with flat brown scales only, and the paraproct simple; female with a large round heavily pigmented preatrial plate in addition to the paired preatrial plates.............(*Aedes*) *nigrotarsis*

15. Hind claws simple in both sexes; female with a pair of hairy processes anterior to the spermathecal eminence..................(*Aedes*) *dux*
   Hind claws unidentate in both sexes; female without paired hairy processes anterior to the spermathecal eminence...................... 16

16. Male with larger claw of mid leg simple, smaller claws of fore and mid legs each with a small tooth (females of this and of the following species indistinguishable except on details of the postatrial area; see Laffoon, 1946: 232)..(*Aedes*) *hamistylus*
   Male with larger claw of mid leg with a prominent tooth, smaller claws of fore and mid legs simple........ ....(*Aedes*) *robertsi*

17. *Ppn* largely clothed with broad overlapping silvery scales; (paratergite with a patch of broad silvery scales) ....(*Finlaya*) *paradissimilis*[4]

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[3] These three species are separable only on details of the male terminalia.

[4] This group of species is separable only on a combination of larval and male terminalic characters which are discussed in the species treatments.

.... (*Finlaya*) *leucopleurus*
.... (*Finlaya*) *luzonensis*
.... (*Finlaya*) *leucomeres*

Ppn not clothed with broad overlapping silvery scales 18

18. Scutum with prominent anterior white scaling 19

Scutum without anterior white scaling, or, if present, occurring only in small spots 22

19. Scutal white-scaled area in female not extending to lateral margin over most of paratergite; male with a line of short stiff curved setae along inner tergal margin of basistyle, followed laterally by a line of thinner setae; baso-tergal scale clump of basistyle with scales narrow, elongate, and mostly of rather uniform length; claspette filament only slightly swollen medially and of uniform texture.... (*Finlaya*) *laoagensis*

Scutal white-scaled area in female extending along lateral margin to wing base, or at least to level of prealar region; male terminalia without the above combination of characters 20

20. Mid femur of female with a median elongate silvery-scaled area on the ventral half of the anterior surface; baso-tergal portion of basistyle with a clump of long setae, none of them striated (one specimen had 2 setae with a very few striations) ....
.... (*Finlaya*) *saperoi*

Mid femur of female with anterior surface dark medially except possibly on extreme ventral margin; baso-tergal portion of basistyle with a clump of specialized scales (to be distinguished from normal abdominal type scales) 21

21. Baso-tergal scale clump of basistyle with some of the scales very broad, others slender and elongate; claspette filament distinctly enlarged medially, the enlarged portion clear
.... (*Finlaya*) *lacteus*[5]

Baso-tergal scale clump of basistyle with scales setiform; claspette filament evenly and only slightly swollen to middle, of uniform texture
.... (*Finlaya*) *niveus*[5]

22. Femora with anterior surface apically dark; scutellum dark-scaled 23

Femora with an apical white spot on the anterior surface, at least on mid and hind legs; scutellum pale-scaled (white or silvery) 28

23. Mesepimeron and meteusternum with a number of short fine brownish hairs present; (male palpi approximately 0.6–0.7 as long as the proboscis; mesepimeron with a patch of brownish-white scales) ....
.... (*Geoskusea*) *baisasi*

Mesepimeron and meteusternum without short fine hairs (however, *curtipes* possesses several long fine hairs just below mesepimeral scale patch) 24

24. Pleuron with a patch of broad white scales on propleuron and mesepimeron and with two patches present on the sternopleuron 25

Pleuron with a few translucent scales (mostly in a single patch), or bare .. 26

25. Mesepimeral scale patch confluent with the dorsal hair tuft; hind femur usually with pale scaling ventrally on basal half of anterior surface ...
.... (*Skusea*) *fumidus*

Mesepimeral scale patch not confluent with the dorsal hair tuft; hind femur darker-scaled anteriorly ....
.... (*Skusea*) *amesii*

26. First hind tarsal segment as long as, or slightly longer than, the hind tibia; acrostichal bristles present; no lower mesepimeral bristles ....
.... (*Rhinoskusea*) *longirostris*

First hind tarsal segment shorter than hind tibia; acrostichal bristles absent; lower mesepimeral bristles present 27

27. Hind femur anteriorly dark; pleuron yellowish-brown; mesepimeron not with several fine hairs between the dorsal hair tuft and the lower me-

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[5] These two species can only be separated on the basis of male terminalic and of larval characters.

sepimeral bristles. . . . . (*Cancraëdes*) *miachaetessus*

Hind femur anteriorly with considerable pale scaling on basal half; pleuron grayish-brown to brown; mesepimeron with several fine pale hairs between dorsal hair tuft and lower mesepimeral bristles. . . . . (*Cancraëdes*) *curtipes*

28. Scutum, femora, and tibiae with small spots of broad silvery scales; median area of vertex mainly with broad white and dark scales. . . . . (*Aedimorphus*) *punctifemore*

Scutum, femora, and tibiae without spots of broad silvery scales; median area of vertex mainly with narrow-curved scales. 29

29. Scutum uniformly scaled on dorsal surface; tibial apices creamy; pleural scale patches dull. . . . . (*Aedimorphus*) *pampangensis*

Scutum variegated with indistinct spots of pale scaling; tibial apices with a white patch; pleural scale patches white. . . . . (*Aedimorphus*) *alboscutellatus*

30. *Ppn* with 10–30 bristles; wing membrane surrounding crossveins clouded; (wings with intermixed pale and dark scaling; lower mesepimeral bristles present). 31

Ppn usually with less than 10 bristles; wing membrane not clouded around the crossveins. 33

31. Scutum sparsely clothed with narrow yellow scales (some scattered brown scales may also be present); female palpi barely one-fourth as long as proboscis; a black and yellow species. . . . . (*Mucidus*) *aurantius quadripunctis*

Scutum with several twisted tufts of erect long white scales; female palpi over one-half as long as proboscis; brown, white, and yellow species. . 32

32. Fore and mid tibiae with a well-developed median white band; fore tibia with apical white band not occupying more than 0.25 of length of segment. . . . . (*Mucidus*) *ferinus*

Fore and mid tibiae without a median white band, occasionally a few pale scales present, however; apical 0.31 or more of fore tibia white-scaled . . . . (*Mucidus*) *laniger*

33. Wings profusely spotted with areas of pale and dark scaling; femora and tibiae spotted and ringed with pale scaling for nearly their whole length. 34

Wings not profusely spotted with areas of pale and dark scaling; femora and tibiae not spotted and ringed with pale scaling. 40

34. Species with yellow, white, and black scaling. 35

Species with black and white scaling. 39

35. Prealar scale patch connected to the dorsal sternopleural patch by a narrow line of broad white scales, from the anterior margin of the dorsal sternopleural patch a similar line extends ventrally and posteriorly to medio-posterior sternopleural scale patch; larger claw of fore and mid male tarsi with a single basal tooth . . . . (*Finlaya*) *stonei*

Prealar scale patch not connected to dorsal sternopleural scale patch with a line of scales, nor is there a line of scales extending ventrally and posteriorly from the dorsal sternopleural patch; larger claw of fore and mid male tarsi bidentate. . 36

36. Male with pale hairs scattered over the dorsal aspect of most of the abdominal tergites; female tergites with pale hairs numerous basally and apically so that there appears to be a thick fringe of them at the junction of the tergites; (proboscis nearly always without apico-ventral black scales) . . . . (*Finlaya*) *luteus*

Male with pale hairs of tergites confined to lateral and apical margins; female tergites with only a sparse row of pale hairs at the junction of the tergites. 37

37. Proboscis without apico-ventral black scales, occasionally a few scattered ones present; basistyle of male ter-

minalia without a tergal subapical scale tuft; (latero-dorsal margins of abdominal tergites II–IV of female dark-scaled, or with yellow scaling present as spots or irregular marks only, not as longitudinal markings; *ppn* with few or no black scales) . . . . (*Finlaya*) *croceus*

Proboscis with a patch of apico-ventral dark scales; basistyle with a tergal subapical elongate scale tuft, in addition to the usual inner median sternally projecting tuft 38

38. Proboscis of male largely dark-scaled laterally and ventrally, except for a median pale band; subapical scale tuft of basistyle dusky; latero-dorsal margins of abdominal tergites II–IV of female with yellow scaling present as spots or irregular marks only . . . . (*Finlaya*) *medleri*

Proboscis of male with considerable pale scaling laterally and ventrally; subapical scale tuft of basistyle largely pale yellow; latero-dorsal margins of abdominal tergites II–IV of female with longitudinal streaks of yellow scaling . . . . (*Finlaya*) *flavipennis*

39. Lateral scutellar lobes covered with broad scales, these white except for a few apical dark ones; segment I of fore tarsus with some basal white scales . . . . (*Finlaya*) *poicilius*

Lateral scutellar lobes with narrow-curved yellowish scales; segment I of fore tarsus without basal white scales . . . . (*Finlaya*) *ananae*

40. Scutum marked with a pattern of several (3–5) narrow longitudinal white or yellow lines, one of the lines being median in position 41

Scutum not marked with a pattern of 3–5 narrow longitudinal pale lines . 47

41. Tarsi all dark except for a small baso-lateral white patch on hind tarsal I . . . . (*Stegomyia*) *aurotaeniatus*

Hind tarsi with basal white bands on at least first 3 segments 42

42. Postspiracular area not scaled; (hind tarsus with basal and apical bands on I–III, a basal band on IV, V dark or else pale above) . . . . (*Finlaya*) *aureostriatus*

Postspiracular area scaled 43

43. Hind tarsi with basal and apical white bands on I–IV, V all white dorsally; mid femora with a conspicuous longitudinal median white line anteriorly . . . . (*Finlaya*) *banksi*

Hind tarsi with basal white bands on I–III (rarely also on IV), V all dark; mid femora without an anterior median line 44

44. Scutum with median longitudinal pale line forked posteriorly at the prescutellar bare space . . (*Finlaya*) *saxicola*

Scutum with median longitudinal pale line not forked posteriorly 45

45. Hind tarsi with the first 4 segments with basal white scaling . . . . (*Finlaya*) *sherki*

Hind tarsi with only the first 3 segments with basal white scaling . . . . 46[6]

46. Prealar scale patch continuous with the upper sternopleural scale patch . . . . (*Finlaya*) *jugraensis*

Prealar scale patch distinctly separated from the upper sternopleural scale patch . . . . (*Finlaya*) *abadsantosi*[7]
. . . . (*Finlaya*) *burgosi*[7]

47. Scutellum with only narrow and narrow-curved scales 48

Scutellum mostly or entirely broad-scaled 51

48. Scutum with considerable areas of white scaling; vertex dorsum largely broad-scaled; (hind tarsal segments III–V dark) . . . . (*Finlaya*) *melanopterus*

Scutum not white-scaled; vertex dorsum largely narrow-scaled 49

49. Hind femur anteriorly pale except for a dark apical portion and along the dorsal margin; proboscis dark-scaled; paratergite of female not scaled . . . . (*Banksinella*) *imprimens*

Hind femur anteriorly speckled with pale scaling; proboscis with evident pale scaling; paratergite of female scaled.......................... 50

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[6] Since the type description of *rizali* (Banks) is incomplete on a number of points, it has been impossible to take it beyond this point in the key.

[7] Separable only on male and larval characters.

50. Subspiracular area scaled; female torus with white scaling........................ (*Aedimorphus*) *vexans nocturnus*

Subspiracular area without scales; female torus not scaled....................... (*Ochlerotatus*) *vigilax ludlowi*

51. Hind femora anteriorly dark, marked with a complete broad white band just before the middle and with a wide ventro-apical white area; lateral scutellar lobes narrow-scaled....................... (*Finlaya*) *harperi*

Hind femora not marked as above; scutellum all broad-scaled........ 52

52. Vertex dorsum narrow-scaled, at least along the mid line; scutum brown-scaled, marked with a rather indefinite pattern of small clusters of yellowish scales; some of the hind tarsal segments with narrow apical yellowish bands........................... (*Aedimorphus*) *mindoroensis*

Vertex dorsum mid line at least partially broad-scaled; scutum not scaled as above; hind tarsal segments not marked with apical yellowish bands.................... 53

53. Vertex dorsum broad-scaled except for a diamond-shaped anterior area of narrow white scales medially; paratergite bare................. 54

Vertex dorsum all broad-scaled (may be a few narrow scales on nape and along eye margins); paratergite scaled (not in *platylepidus*)........ 59

54. All three lobes of scutellum largely covered with broad white scales... 55

Only mid scutellar lobe with broad white scales, lateral lobes covered with broad black scales..........57[8]

55. Median stripe of scutum extending posteriorly to the scutellum................... (*Stegomyia*) *bambusicolus*

Median stripe of scutum extending only to level of wing bases....... 56

56. An area of broad white scales on the lateral margin of the scutum just before level of wing base.......................... (*Stegomyia*) *laffooni*

No area of broad white scales on lateral scutal margin............................ (*Stegomyia*) *arboricolus*

57. Scales of *apn* and *ppn* all dark..................... (*Stegomyia*) *albolineatus*

At least some of the scales of *ppn* pale, usually some pale scales on *apn* also........................... 58

58. Median scutal stripe extending posteriorly to scutellum; *ppn* with narrow-curved creamy scales only .... (*Stegomyia*) *hoogstraali*

Median scutal stripe extending posteriorly only to level of wing bases; *ppn* with narrow dark scales dorsally and broad white scales below....................... (*Stegomyia*) *boharti*

59.[9] Hind tarsal segments IV–V all dark. 60

Hind tarsal segments IV–V with white markings (V sometimes all dark in male of *gardnerii*)............... 62

60. Hind tarsal segment III with only a narrow basal white band; proboscis with white markings; (scutum with prominent white scaling; a lower mesepimeral bristle present; hind tarsus with narrow basal bands on I–III)........ (*Christophersiomyia*) *brayi*

Hind tarsal segment III dorsally all white, or nearly so; proboscis dark-scaled......................... 61

61. Scutum narrow-scaled, with an obovate antero-median patch of silvery scales; hind tarsal segment II with a broad basal band; paratergite scaled........ (*Stegomyia*) *meronephada*

Scutum covered with plate-like broad dark scales; hind tarsal segment II all dark or with just a very few basal white scales; paratergite bare.......................... (?) *platylepidus*

62. Hind tarsal segment III all dark, broad basal bands on I–II, IV–V all white (may be some apical black scales on V); (scutum marked with

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[8] *Aedes* (*Stegomyia*) sp. near *boharti* is similar to *boharti* except that all three scutellar lobes are covered with broad black scales.

[9] *A. wainwrighti* at present cannot be keyed beyond this point since hind tarsal segments II–V are missing from the single known specimen.

a broad obovate median longitudinal white band that tapers to posterior margin) . . . . (*Stegomyia*) *mediopunctatus perplexus*

Hind tarsal segments I–V with white markings 63

63. Tibiae ringed with white just before the middle; hind tarsal segments IV–V all white, may be a few apical black scales on IV; (scutum marked with a pair of narrow subdorsal white lines from anterior margin halfway to level of wing bases, a large white patch laterally before wing base, and 3 short longitudinal pale lines between the wing bases) . . . . (*Stegomyia*) *desmotes*

Tibiae not ringed near the middle; hind tarsal IV with a distinct apical dark band 64

64. Hind tarsal segment V with at least some dark scaling apically, occasionally all dark; the scales along the posterior portion of the scutum all broad; scutum with a pair of broad subdorsal white bands anteriorly and a large white patch before the wing base . . . . (*Stegomyia*) *gardnerii*

Hind tarsal segment V all white; the scales along the posterior margin of the scutum narrow or mostly so; scutum not marked as above 65

65. Scutum with a pair of thin longitudinal submedian lines and a paired broadened antero-lateral crescent-shaped marking (composed of broad silvery scales); female clypeus with white scaling . . (*Stegomyia*) *aegypti*

Scutum with a narrow tapered median longitudinal band; female clypeus not scaled 66

66. Dorsal abdominal bands basal, detached from the lateral spots; pleural scale patches not forming 2 sharply differentiated longitudinal white bands . . . . . . (*Stegomyia*) *albopictus*

Dorsal abdominal bands subbasal on more posterior segments, attached on at least some segments to the lateral spots; pleural scale patches arranged into 2 sharply differentiated longitudinal white bands . . . 67

67. Mid femur anteriorly with a median longitudinal white line, may be poorly developed in female (rarely absent); scutum with a line of white scales on antero-lateral margin . . . . (*Stegomyia*) *paullusi*

Mid femur without anterior median longitudinal pale markings; scutum without a line of white scales on antero-lateral margin . . . . (*Stegomyia*) *scutellaris*

Fourth Instar Larval Key

1. Anal plate with an acus (otherwise bare except possibly for spicules on posterior margin) 2

Anal plate without an acus 7

2. Comb of 8–10 teeth in a row . . . . (*Aedimorphus*) *vexans nocturnus*

Comb of 16 or more scales in a patch . 3

3. Antenna slender, very few fine spicules scattered near base; comb of 40–80 scales 4

Antenna rather stout, large spicules scattered over most of length; comb of 16–28 scales 5

4. Head hair 4 with 13–16 branches; ventral brush with 10 tufts . . . .
. . . . (*Finlaya*) *leucopleurus* (in part)
. . . . (*Finlaya*) *aureostriatus* (in part)

Head hair 4 with 4–8 branches; ventral brush with 12 tufts 48

5. Antennal hair with 1–4 branches; ventral brush with 15–17 tufts . . . . (*Ochlerotatus*) *vigilax ludlowi*

Antennal hair with 5–13 branches; ventral brush with 12 tufts 6

6. Head hair 5 with 6–7 branches; head hair 6 with 4–6 branches; siphon index about 7.0 . . . . (*Aedimorphus*) *pampangensis*

Head hair 5 with 3–4 branches; head hair 6 with 2–4 branches (usually 3); siphon index 3.5–3.9 . . . . (*Aedimorphus*) *alboscutellatus*

7. Mouth brushes forming stout, serrate-tipped rods; ventral brush of more than 20 tufts 8

Mouth brushes normal, usually with comb-like tips; ventral brush of no more than 17 tufts 9

8. Ventral brush with 30–32 tufts; pentad hair 2 single.... (*Mucidus*) *ferinus*

Ventral brush with 22–26 tufts; pentad hair 2 double .... (*Mucidus*) *aurantius quadripunctis*

9. Comb teeth in a straight or irregular row (3–24 in number) 10

Comb teeth in a patch or double row (14–100 in number) 34

10. Ventral brush of 8–10 tufts 11

Ventral brush of 12–17 tufts 24

11. Head hair 5 with 4–20 branches; head hair 12 with 10–25 branches 12

Head hair 5 with 1–2 branches; head hair 12 with 2–5 branches 18

12. Pecten with 2–6 teeth; antennal hair tuft with 1–5 branches 13

Pecten with 12–24 teeth; antennal hair tuft with 5–17 branches 15

13. Posterior margin of anal plate with a small area of short spines; stellate hairs of body with 3–6 slender branches .... (*Stegomyia*) *hoogstraali*

Posterior margin of anal plate with a fringe of strong spines; stellate hairs of body with 6–19 stout branches .. 14

14. Ventral brush with all elements borne on the barred area .. (*Stegomyia*) *laffooni*

Ventral brush with 2 tufts off the barred area basally ....
(*Stegomyia*) *albolineatus*[10]
.... (*Stegomyia*) *boharti*
.... (*Stegomyia*) *arboricolus*

15. Comb teeth fringed to just before apex; ventral brush of 10 tufts .... (*Finlaya*) *niveus*

Comb teeth not fringed beyond middle; ventral brush of 8 tufts 16

16. Antennal hair tuft with 10–17 branches; spicules on posterior margin of anal plate minute..... (*Finlaya*) *saperoi*

Antennal hair tuft with 5–8 branches; spicules on posterior margin of anal plate stout, long 17

17. Head hair 4 with 8–10 branches; 5 with 6–8 .... (*Finlaya*) *laoagensis*

Head hair 4 with 13–14 branches; 5 with 9–12 .... (*Finlaya*) *albolateralis*

18. Siphon with a distinct, narrowly attached acus .... (*Finlaya*) *harperi*

Siphon without a true acus 19

19. Comb teeth borne on a sclerotized plate 20

Comb teeth not borne on a sclerotized plate 22

20. Barred area of ventral brush not connected laterally; a small patch of spines laterally on the posterior margin of the anal plate .... (*Stegomyia*) *mediopunctatus perplexus*

Barred area of ventral brush connected to a prominent sclerotized plate on each side; anal plate smooth 21

21. Head hairs 5 and 7 single; ventral brush hairs single .. (*Stegomyia*) *desmotes*

Head hair 5 with 3–6 branches; 6 with 3–7 branches; ventral brush hairs double or triple . (*Stegomyia*) *bambusicolus*

22. Meso- and metathoracic pleural spines conspicuous, stout, elongate, and usually curved near apex; comb teeth with prominent lateral spines at the base of the long central spine .... (*Stegomyia*) *aegypti*

Meso- and metathoracic pleural spines slender, straight, and not conspicuous; comb teeth bearing only a fine fringe at the base of the long spine. 23

23. Ventral brush with 2–3 hairs off the barred area basally; *lh* inserted in a clear area within the anal plate.... .... (*Stegomyia*) *gardnerii*

Ventral brush with all hairs borne within the barred area; no clear area around point of attachment of *lh*
.... (*Stegomyia*) *scutellaris*
.... (*Stegomyia*) *paullusi*
.... (*Stegomyia*) *albopictus*

24. Ventral brush with 14 or more tufts .. 25

Ventral brush with 12 (rarely 11 or 13) tufts 27

25. Ventral brush of 16–17 tufts; anal plate complete . (*Banksinella*) *imprimens*

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[10] These species have been provisionally separated as follows:

Anal gills finger-like, about twice the length of the anal plate (1.6–2.2) .... *albolineatus*

Anal gills tapered from base, about 1.5–1.8 times longer than anal plate .... *boharti*

Anal gills tapered from base, occasionally somewhat lanceolate; dorsal pair 1.05–1.15 times longer than anal plate .... *arboricolus*

Ventral brush of 14–15 tufts; anal plate incomplete................ 26

26. Head hairs 5 and 6 with 3 (sometimes 2) branches with the median branch stouter and much longer than the lateral branches; antennal spicules darkly pigmented... *(Aedes) nigrotarsis*

Head hair 5 with 1–4 branches; hair 6 single, stout; antennal spicules pale .... *(Aedes) uncus*

27. Head hair 15 developed as a stout, curved, horn-like projection...... .... *(Stegomyia) meronephada*

Head hair 15 normal, small, usually branched...................... 28

28. Pecten teeth evenly spaced, 20–24 in number............ *(Finlaya) lacteus*

Distal pecten teeth more widely spaced, 5–20 in number.......... 29

29. Ventral brush with 3–5 tufts off the barred area basally; comb teeth with a strong central spine about as long as the base of the teeth; antennal spicules stout, dark............ .... *(Banksinella) lineatopennis*

Ventral brush with 1–2 tufts off the barred area basally; comb teeth with central spine no more than one-half as long as base of teeth, or with no prominent central spine present; antennal spicules small, pale.......................... 30

30. Comb teeth with a complete apical fringe, no prominent terminal spine; pentad hair 2 with 4–6 branches; mentum with 11–13 lateral teeth.. .... *(Aedes) butleri*

Comb teeth with a distinct terminal spine; pentad hair 2 with 1–3 branches...................... 31

31. Mentum with 8–11 lateral teeth; anal gills 1.0–1.5 times as long as anal plate.................. *(Aedes) dux*

Mentum with 13 or more lateral teeth; anal gills at least 1.7 times as long as anal plate...................... 32

32. Head hair 5 with 2–3 branches; hair 6 with 2–4 branches.... *(Aedes) robertsi* .... *(Aedes) hamistylus*

Head hair 5 with 5–10 branches; hair 6 with 4–8 branches............. 33

33. Mentum with 18–20 lateral teeth; prothoracic hair 2 single; prothoracic hair 8 double..... *(Aedes) campylostylus*

Mentum with 13–18 lateral teeth; prothoracic hair 2 single or double (usually double); prothoracic hair 8 single or double (usually single) .... *(Aedes) johnsoni* .... *(Aedes) margarsen*

34. Antennal hair with 5–7 branches (rarely 4)......................... 35

Antennal hair with 1–4 branches.... 36

35. Siphon index 3.4–3.8; pecten teeth with lateral fringe; comb scales with blunt, fringed tips............. .... *(Rhinoskusea) longirostris*

Siphon index about 2.7; pecten teeth with 2–4 large denticles; comb scales simple, sharply pointed.... .... *(Cancraëdes) curtipes*

36. Ventral brush with 10 tufts (rarely 9 or 11)........................ 37

Ventral brush with 12 tufts (rarely 11 or 13)........................ 46

37. Anal plate bare, or with a few small spicules...................... 38

Anal plate with long spines or scales on posterior margin............ 40

38. Pecten with 23–26 close-set teeth with basal denticles.................. .... *(Finlaya) leucopleurus* (in part) .... *(Finlaya) aureostriatus* (in part)

Pecten with 7–17 teeth; each with fringe along entire ventral margin. 39

39. Head hair 4 with 6–10 branches..... .... *(Skusea) amesii*

Head hair 4 with 13–20 branches.... .... *(Skusea) fumidus*

40. Pecten with 18–29 teeth........... .... *(Finlaya) melanopterus*

Pecten with 4–13 teeth............ 41

41. Preclypeal spine with at least 2 branches (rarely single in *poicilius*); prothoracic hair 0 large, stellate, with at least 9 branches; margin of anal plate ventral to *lh* with large spines........................ 42

Preclypeal spine single; prothoracic hair 0 small, with not more than 5 branches; no spines ventral to *lh* on margin of anal plate............ 44

42. Mandible with a large dark tooth anterior to the longest tooth; scales in distal row of comb patch without a pair of distinct lateral denticles near base; (hair 11 of meso- and metathoracic pleural groups short, weak, with 2–4 branches) . . . . (*Finlaya*) *stonei*
    Mandible without a large dark tooth anterior to the longest tooth; scales in distal row of comb patch with a paired baso-lateral denticle 43

43. Preclypeal spine with 3–6 branches; head hair 4 candelabra-like (rarely fan-like), with 11 or more branches; hair 11 of meso- and metathoracic pleural groups prominently stellate, with many branches . . (*Finlaya*) *ananae*
    Preclypeal spine double (rarely single); head hair 4 with 3–7 branches; hair 11 of meso- and metathoracic pleural groups single, stoutly spinose, short . . . . (*Finlaya*) *poicilius*

44. Hair 11 of meso- and metathoracic pleural groups single, fairly long, stout, spinose; head hair 7 with 2–3 branches . . . . (*Finlaya*) *luteus*
    . . . . (*Finlaya*) *croceus*
    Hair 11 of meso- and metathoracic pleural groups very short, slender, single or double, not spinose; head hair 7 with 4–7 branches 45

45. Siphon and anal plate very dark brown . . . . (*Finlaya*) *flavipennis*
    Siphon and anal plate pale yellow . . . . (*Finlaya*) *medleri*

46. No stellate hairs present; body integument not pilose 47
    Stellate hairs developed to various degrees; integument slightly to densely pilose 49

47. Head hair 5 with 7–12 branches; posterior margin of anal plate with a patch of strong spines . (*Finlaya*) *banksi*
    Head hair 5 with 1–2 branches; posterior margin of anal plate with very short or fine spicules only 48

48. Lateral hairs on abdominal segments I and II double, stout, darkly pigmented; fringe on apical margin of some comb scales with central element enlarged . . (*Finlaya*) *paradissimilis*
    Lateral hairs on abdominal segments I and II with 3–4 branches, moderately stout, brown in color; apical fringe on comb scales even . . . . (*Finlaya*) *luzonensis*

49. The apical 2–5 pecten teeth ventrally out of line with the others . . . . (*Finlaya*) *abadsantosi*
    . . . . (*Finlaya*) *sherki*
    The apical 2–5 pecten teeth not ventrally out of line with the others (may be dorsally out of line in *burgosi*) 50

50. Metathoracic hair 7 with 7–9 branches, normal, slender, elongate; *lh* with 2 or more branches . . . . (*Finlaya*) *burgosi*
    Metathoracic hair 7 with 3–5 branches, relatively short, stout, stellate-like, barbed; *lh* single 51

51. No simple (without denticles) pecten teeth apically and no teeth distad of the siphon hair tuft base . . . . (*Finlaya*) *jugraensis*
    Two to 4 simple teeth beyond the base of the siphon hair tuft and usually 1–3 simple teeth basad of the hair tuft 52

52. Mesothoracic hair 1 with 1–4 branches; metathoracic hair 1 with 1–5 branches . . . . (*Finlaya*) *saxicola*
    Mesothoracic hair 1 with 8–9 branches; metathoracic hair 1 with 11–14 branches . . . . (*Finlaya*) sp. near *saxicola*

SYSTEMATICS

Genus *AEDES* Meigen

1818. *Aedes* Meigen, Syst. Beschr. 1: 13. Genotype: *cinereus* Meigen.

ADULT: Distinct from all the other Philippine genera of the tribe Culicini, except *Mansonia* (*Mansonioides*) and *Armigeres* (*Armigeres*), by the possession of postspiracular bristles. From the former, *Aedes* is distinct in lacking specialized teeth on the female eighth tergite and in not having asymmetrical broad wing scales. From the latter, the genus *Aedes* is distinct with certainty only in the larval stage, i.e., by the presence of a pecten on the siphon. However, the general habitus of the *Armigeres* adult is relatively distinct, and the proboscis is generally stouter and more conspicuously recurved. Other important characters of the genus *Aedes* are: Prescutellar bristles present (not in *platylepidus*). *Apn* lobes widely separated. Postnotum without setae. Spiracular bristles absent. Upper margin of meron above level of base of hind coxa. Pulvilli absent, or hair-like. Squama with a fringe of bristles (more than four). Wing with distinct microtrichia. Vein 6 reaching beyond base of fork of vein 5.

LARVA: Not distinct from that of *Heizmannia*, but distinguished from the other genera in the Philippines by the combination of the following characters: Siphon with a pecten and with only a single pair of ventral hair tufts, and ventral brush of eighth segment including at least four hairs.

DISTRIBUTION: Worldwide. Of the 23 recognized aedine subgenera, 12 are known to occur in the Philippines. The following subgenera have not yet been found there: *Chaetocruiomyia*, *Diceromyia*, *Dunnius*, *Howardina*, *Indusius*, *Leptosomatomyia*, *Levua*, *Macleaya*, *Pseudoskusea*, *Kompia*, and *Soperia*.

Faunistically the Philippine Islands are a part of the Oriental Region. This is well illustrated in the genus *Aedes*. Of the 74 known Philippine species, only 11 also occur in the Australasian Region, 2 in the Ethiopian Region, and 1 in the Palaearctic Region. Within the Oriental Region the Philippine *Aedes* fauna is an intimate part of the Malayan Subregion. However, as would be expected from the isolated position of the Philippines, the *Aedes* fauna there is particularly rich in endemic forms, 46 species at present being in this category.

Subgenus MUCIDUS Theobald

1901. *Mucidus* Theobald, Mon. Cul. 1: 268. Genotype: *alternans* Westwood (Australia).

ADULT: Distinguished from all the other subgenera in the Philippines by either of the following: Wing membrane surrounding crossveins 2–3, 3–4, and 4–5 clouded, these three approximated; *ppn* with 10–30 bristles. Other characters: Palpi of male as long as or longer than proboscis. Vertex dorsum and scutellum narrow-scaled. Paratergite scaled. Lower mesepimeral bristles present. Fore and mid tarsal claws of male unequal, larger claw bidentate or unidentate, smaller unidentate; hind claws equal, simple or unidentate; of female equal, each unidentate. *Terminalia:* Basistyle with a weakly developed basal lobe, but without an apical lobe. Mesosome simple. Claspettes present.

LARVA: Distinguished from all the other subgenera in the Philippines by any of the following: Mouth parts modified for predacity, the mouth brushes forming matted tufts of serrate-tipped rods and the mandibular teeth very large and strong; head hair 4 considerably external to hairs 5 and 6; ventral brush extending the complete length of the anal segment. Habitat—temporary ground pools.

DISTRIBUTION: The 13 known species and subspecies are confined to the tropics of the Ethiopian, Oriental, and Australasian Regions. Two species and one subspecies are known from the Philippines.

SYSTEMATICS: The subgenus has been divided by Edwards (1932) into two groups: Group A (*Mucidus*) and Group B (*Pardomyia*) (see adult species key for separation points). Group A is represented in the Philippines by *ferinus* Knight and *laniger* (Wiedemann) and Group B by *aurantius quadripunctis* (Ludlow).

Aedes (Mucidus) ferinus Knight

1947. *Aedes* (*Mucidus*) *ferinus* Knight, Jour. Wash. Acad. Sci. 37: 316 (males, females, pupae, larvae). Type locality: Philippines. San Ramon (Penal Farm), City of Zamboanga Prov., Mindanao (Laffoon and Knight). Type: Male (holotype), with associated larval and pupal skins, in U. S. N. M.†

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Luzon: Olongapo, Subic Bay, Zambales Prov. Mindanao: San Ramon (Penal Farm) and Zamboanga, City of Zamboanga Prov. A.N.S.P. Leyte: Dulag. C.C. (1 female). Luzon: San Miquel, Tarlac Prov. (Franclemont).

Unknown outside the Philippines.

DISCUSSION: In addition to being closely related to *laniger* (Wied.), this species is also similar to *scatophagoides* (Theo.), from which it differs in tarsal markings and male genitalia (Knight, 1947*a*: 319). The pupal abdomen has been figured by Knight and Chamberlain (1948: fig. 25).

Aedes (Mucidus) laniger (Wiedemann)

1821. *Culex laniger* Wiedemann, Dipt. Exot., p. 9 (female). Type locality: Java. Type: In Copenhagen Museum.
1901. *Mucidus laniger* Wiedemann. Theobald, Mon. Cul. 1: 269. Different combination.
1906. *Mucidus mucidus* Karsch. Banks, Phil. Jour. Sci. 1: 983. Misidentification.
1908. *Mucidus mucidus* Theobald. Leicester, Cul. Malaya, p. 69. Error in author assoc., and misidentification.

Adult partially described by Barraud (1934: 147) and Knight (1947*a*: 320). The latter paper also discusses the systematics of this species. The larva is undescribed.

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Mindanao: Ludlow Barracks, Parang. Pettit Barracks, Zamboanga, City of Zamboanga Prov.

Literature records. Mindoro: Calapan (Edwards, 1929: 5). Luzon: Manila, Manila Prov. (Banks, 1906: 983). This record is to be questioned since the species was merely listed as *Mucidus mucidus* Karsch and thus could equally well be *ferinus.*

Known also from Sumatra, Celebes, Java, Malaya, Indo-China, Ceylon, and (?) Assam.

DISCUSSION: Because of the incompleteness of Wiedemann's description and because of the discrepancies existing between it and the specimens assigned to this species by various authors, the exact identity of *laniger* will remain doubtful until either the types, or specimens from the type area, are studied. It is quite possible that, when more material is available from the Philippines, *ferinus* and the above-mentioned Philippine specimens of *laniger* will prove to be one and the same species. Whether or not the Philippine material will then prove to be specifically different from that of the Netherlands East Indies remains to be seen.

Aedes (Mucidus) aurantius quadripunctis (Ludlow)

1910. *Pardomyia quadripunctis* Ludlow, in Theobald, Mon. Cul. 5: 608 (female). Type locality: Philippines. Parang, Mindanao (Page). Type: Female (holotype), in U. S. N. M.†
1932. *A.* (*M.*) *aurantius* var. *quadripunctis* Ludlow. Edwards, Genera Insectorum, fasc. 194: 135. Different combination.
1945. *Aedes* (*Mucidus*) *quadripunctis* (Ludlow). Bohart, Syn. Phil. Mosq., p. 55. Different combination.

Adult and larva have been fully described by Knight (1947*a*: 322).

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Mindanao: Type female, Parang. A.N.S.P. Leyte: Tacloban. Dulag.

Unknown outside the Philippines.

DISCUSSION: In a previous treatment (Knight, 1947*a*), the senior author followed Bohart (1945: 55) in considering *quadripunctis* a full species. However, in view of the obviously close relationship of this form to *aurantius* and its subspecies, we have here considered it a subspecies (following Edwards, 1932: 135, except that he classed *quadripunctis* as a variety). From the little that we know at present of the *aurantius* complex it would appear that the subspecies are truly geographic in nature, as follows: *a. quadripunctis* from the Philippines; *a. aurantius* (Theobald) from Malaya, Borneo, Sumatra, and New Guinea; *a. chrysogaster* (Taylor) from Queensland; and *a. painei* Knight (formerly *a. nigrescens*) from the Solomons.

This subspecies is primarily distinct from the other members of the *aurantius* complex on the color of the scutal scaling.

Subgenus OCHLEROTATUS Lynch Arribalzaga

1891. *Ochlerotatus* Lynch Arribalzaga, Rev. Mus. La Plata 2: 143. Genotype: *confirmatus* L. A. (syn. of *scapularis* Rondani) (South America).

ADULT: Distinguished from all the other subgenera in the Philippines by a combination of the following: Male palpi as long as the proboscis, mesosome simple, claspettes present and with filament setiform, and basistyle with a distinct basal lobe. Other characters are: Male palpi approximately equal to the proboscis in length; segment III with apex upturned, IV and V declined; the apex of III and all of IV and V with a dense band of long, laterally and ventrally directed hairs. Vertex dorsum and scutellum narrow-scaled. Acrostichal and dorso-central bristles present. Paratergite usually with sparse scaling. Lower mesepimeral bristles absent. Fore and mid tarsal claws of male unequal, larger claw bidentate (mid of *vigilax ludlowi* has median tooth reduced to a swollen area), smaller unidentate; of female equal and unidentate; hind claws simple in both sexes. *Terminalia:* Basistyle with a distinct basal lobe. Dististyle appendage apical. Mesosome simple. Claspettes present, with distinct spine- or bristle-like filament.

LARVA: Separable from all the other subgenera in the Philippines, except *Aedimorphus* and some specimens of the *Finlaya* species *leucopleurus* and *aureostriatus*, by the possession of an acus on the anal plate. Antennal hair tuft with 1–4 branches. Head hair 4 with 4–5 branches, 5 and 6 single. Comb with 23–28 scales in a patch. Siphon with an attached acus; 5–12 pecten teeth, evenly arranged. Anal plate incomplete. Ventral brush with 15–17 tufts, all but the basal two arising from a laterally connected barred area. Habitat—temporary, brackish ground pools.

DISTRIBUTION: This is a very large subgenus with many species in all the regions of the world except the Ethiopian and Oriental, where it is represented by only a few species. The single form found in the Philippines is a subspecies of a species common throughout the Australasian Region.

SYSTEMATICS: Edwards (1932: 136) divided the subgenus into eight groups, with the single Philippine species falling into Group A (*taeniorhynchus*-group: *Culicelsa*). This group is distinguished by the absence of a definite apical lobe on the basistyle, and in having the claspette filament bristle-like.

Aedes (Ochlerotatus) vigilax ludlowi (Blanchard)

Figs. 2, 3

1903. *Culex annulifera* Ludlow (nec E. Blanchard, 1852), Jour. N. Y. Ent. Soc. 11: 141 (females). Type locality: Philippines. Mangarin, Mindoro (Suggs). Type: Female lectotype here designated from a series of nine female cotypes in the U. S. N. M.† One female cotype also exists in the British Museum.

1904. *Culex annuliferus* Ludlow. Ludlow, Can. Ent. 36: 72. Emendation.

1905. *C. Ludlowi* R. Blanchard, Les Moust., p. 630. Nom. nov.

1917. *Ochlerotatus annuliferus* (Ludlow). Edwards, Bul. Ent. Res. 7: 215. Different combination.

1922. *Aëdes* (*Ochlerotatus*) *vigilax* (Skuse). In part. Edwards, Bul. Ent. Res. 13: 99. Synonymized *ludlowi*.

1925. *Culex ludlowi* Theobald. Dyar and Shannon, Ins. Insc. Mens. 13: 76. Error in author association.

1929. *annulipes* Ludl. Edwards, Notulae Ent. 9: 2. In error for *annulifera* when quoted as a synonym of *vigilax*.

ADULT: A medium-sized brown species with pale markings on the proboscis, scutal scales brown (female) or brownish-golden (male), abdominal tergites possessing straight basal white bands, and all the hind tarsal segments marked by basal white bands.

Male. Length of wing 3.0–3.5 mm. *Head:* Proboscis dark, marked with a pale-scaled area beginning at basal one-third on the ventral and lateral aspects and extending to just beyond the middle, the medial portion of this band extending onto the dorsum and forming a complete band. Palpus approximately equal to proboscis in length, with basal white rings on the last three segments. Torus bare. Vertex dorsally with pale narrow scales and pale and dark upright-forked scales (the pale uprights being medial and the dark ones lateral); laterally with a patch of broad creamy scales. *Thorax:* Scutum clothed with small narrow brownish-golden scales; the scales on the prescutellar area and on the scutellum narrow and pale yellow. *Apn* with narrow-curved pale yellowish scales, sometimes a few broadened scales also apparent; *ppn* rather thinly covered with mixed narrow and broad dark scales (the broad scales being mostly ventral), in addition there are a few narrow yellow scales present dorsally and a few broad pale scales ventro-posteriorly. Following pleural areas each with a small patch of broad cream-colored scales: propleural, paratergite (very few and frequently none), postspiracular, prealar (below the knob), upper sternopleural, medio-posterior sternopleural, and upper mesepimeral (this patch begins on the anterior border adjacent to the upper sternopleural patch; in addition there is a more or less detached group of mixed broad and narrow pale scales associated with the hair tuft). No lower mesepimeral bristles. *Legs:* Femora dark-scaled, anteriorly marked with scattered pale scaling, posteriorly partially pale-scaled (the hind femur extensively so). Tibiae dark, fore and mid with posterior pale scaling. Fore and mid tarsi with narrow basal white bands on I–III; hind tarsus with basal white bands on all segments, broad on II–V. Fore tarsal claws unequal, the larger claw bidentate, the smaller unidentate; mid tarsal claws unequal, the larger claw with a basal tooth and a swollen area medially, the smaller unidentate; hind tarsal claws equal, simple. *Wing:* Dark-scaled. *Abdomen:* Tergite I with a lateral patch of creamy scales, II–VII with straight basal creamy-white bands. Sternites pale-scaled with apical dark-scaled bands. *Terminalia:* Basistyle with a prominent, densely setose basal lobe; two rather stout bristles subapically on the inner tergal margin. Dististyle appendage apical. Claspette filament spine-like. Ninth tergite lobes each bearing 3–4 bristles.

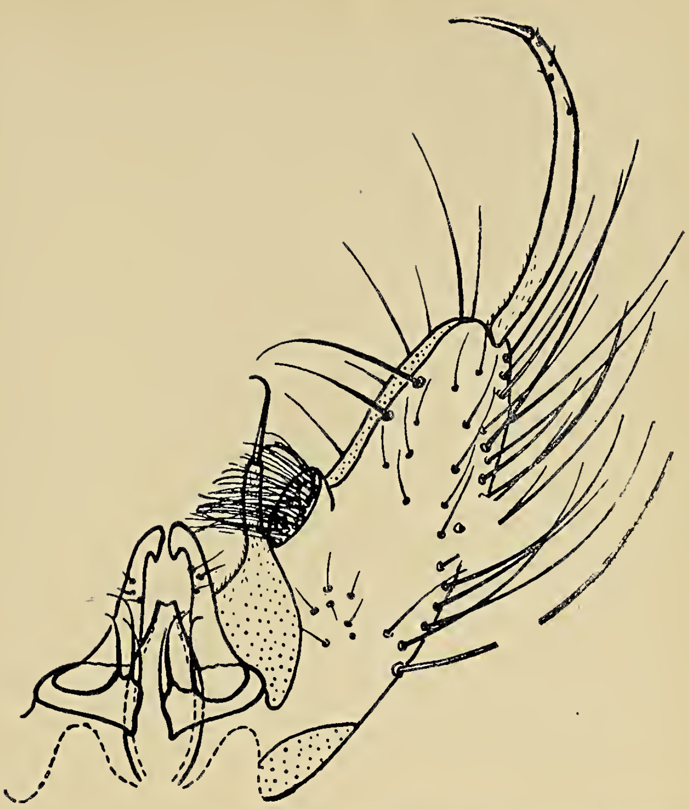

FIG. 2. *A.* (*Ochlerotatus*) *vigilax ludlowi.* Male terminalia (Luzon).

Female. Length of wing approximately 3.2–3.5 mm. Proboscis dark with creamy scaling laterally and ventrally from level of palpal apex to just beyond middle, the pale-scaled area sharply delimited apically; pale scaling may extend onto dorsal surface. Palpus approximately one-sixth the length of the proboscis; dark with apex narrowly white-scaled. Torus bare or with a few dark hairs. Vertex with upright-forked scales all dark; the lateral patch of broad creamy scales with a median band of broad black scales. Scutal scales more brownish than in male, indefinite light and dark areas usually apparent; prescutellar, supra-alar, and scutellar bristles dusky. *Ppn* densely covered with narrow and narrow-curved dark scales, a few broad dark and pale scales may be present ventrally and posteriorly. Pleural scale patches more strongly developed than in male, always a few scales on paratergite. Fore and mid femora more extensively pale-scaled posteriorly than in male. Tarsal claws equal, fore and mid claws each unidentate, hind claw simple. Wing with or without a basal posterior line of pale scales on the costa, may also be a few pale scales basally on vein 1 and scattered elsewhere. Tergite I with a few baso-median pale scales and a lateral white band; V–VII (sometimes only VI–VII) with narrow creamy apical bands; sub-basal lateral creamy spots present on II–VI. Sternites VI–VII with a pale apical band; on II–VI the pale-scaled area medially may extend to the posterior margin.

LARVA: *Head:* Antenna sparsely spiculate; antennal hair with 1–4 branches, inserted medially. Mouth brush with comb-like tips. Preclypeal spines stout, curved, darkened. Hair 4 minute, with about 4–5 branches; 5 and 6 single, well-produced; 7 with 7–10 branches; 8 and 9 with 2–3; 12 with 3–5; 13 single; 14 with 1–2; 15 with 2–4; 17 single; 18 with 1–2; 20 with 3–4. Mentum with 8–10 teeth. *Abdomen:* Dorso-lateral hairs on I and II with 3–4 branches. Lateral hairs on I to VI double or triple. Pentad hair 1 with 2–4 branches; 3 with 9–15; 5 with 4–6. Comb with 23–28 small acutely tapered scales in a patch, each with a lateral fringe from base to apex. Siphon pale, short and broad, acus present; 5–12 pecten teeth, each with several basal denticles; siphon hair tuft inserted medially and just before apex of last pecten tooth, with 10–13 faintly plumose branches. Anal plate narrowly incomplete, some small denticles present dorsally on the posterior margin; *lh* single; *isc* with 9–11 branches; ventral brush extends nearly the whole length of the anal plate, of 15–17 tufts, each with 4–12 branches, all but the basal two arising from a connected barred area. Anal gills very short, tapered from near base to a round apex; dorsal pair approximately one-half as long as the anal plate and slightly longer than the ventral pair.

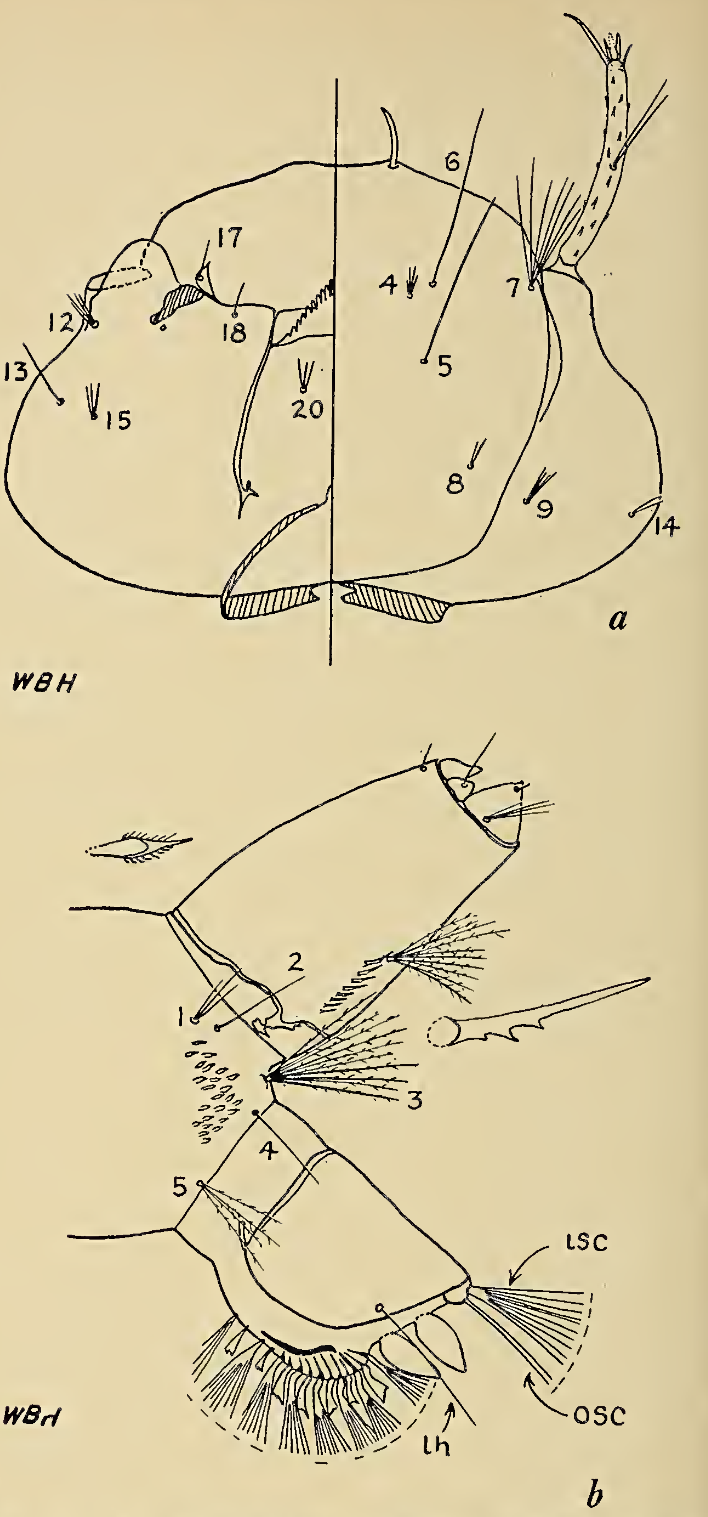

FIG. 3. *A.* (*Ochlerotatus*) *vigilax ludlowi.* Larva (Mindoro). *a*, Head; *b*, terminal segments.

BIONOMICS: The only information found in the literature for the adult of this subspecies is a note by Ludlow (1905:135) stating that adults were "caught in woods." The single female cotype specimen in the British Museum is labeled from "mangroves."

Judging from the fact that 6 months extensive collecting in the Philippines produced only two collections of *vigilax ludlowi* (both larval), this subspecies is apparently rather uncommon. Both of these collections were taken from small temporary ground pools surrounding rice paddies. The pools were recorded as being open to the sun, containing many algae, and possessing water rusty in appearance. Unfortunately no record was made as to whether or not the water of the pools was brackish in nature. However, Dr. E. S. Ross collected this species on Mindoro from shaded, temporary brackish pools at the edge of salt marsh. Penn (1948: 245) reported a larval collection taken on Mindoro from a sunlit fresh-water pool with a *p*H of 6.0.

Aedes vigilax vigilax (Skuse), which is a widespread coastal species in the Australasian and Oriental Regions (but not reported from the Philippines), is a brackish-water breeder of great economic significance. After periods of unusually high tides the larvae occur in tremendous numbers in brackish pools along the seacoast just above the normal high-tide level. The adults soon emerge in great swarms, and since they are vicious and persistent day and night biters, they quickly succeed in seriously impeding all outdoor human activities in the surrounding area. As with the salt marsh mosquitoes of the United States, the adults of *v. vigilax* will travel or drift considerable distances inland. Hill (1925: 71) reported that *v. vigilax* can occasionally be found in fresh water, and that larvae from such breeding sites possess longer and narrower anal gills than those from brackish water.

DISTRIBUTION: *Specimens examined.* U.S.N.M. (5 males, 11 females, 2 sets assoc. skins). Luzon: Olongapo, Subic Bay, Zambales Prov. (Zolik and MacMillan). Mindoro: Type females, Mangarin. C.A.S. (2 males, 2 females, 2 larvae, 1 set assoc. skins). Mindoro: Nr. mouth of Labangan River (Ross).

Literature records. Mindanao, Panay, Mindoro, Luzon (all Bohart, 1945: 56). Luzon: Manila (Edwards, 1929*a*: 2). Mindoro: Caminawit Pt. (Penn, 1948: 245).

Not known from outside the Philippines.

DISCUSSION: The Philippine form is treated here as a distinct subspecies of *vigilax* (Skuse) on the basis of the scaling of *ppn* in the female. In *v. vigilax* this area is covered with flat-lying slightly elongate broad scales, except for a fringe of narrow dark scales dorsally. The broad scales are dark except for a small ventral posterior patch of pale ones. The type of *v. vigilax* has not been seen by us, but the types of the synonyms *uniformis* Strickland (female) and *marinus* (Theobald) (male, female), which are in the British Museum, have been. In addition, a series of Australian specimens in the British Museum and two females from the New Hebrides which are in the U. S. National Museum have been studied. In all these specimens of *v. vigilax*, *ppn* was found to be scaled as described above. No other differences have been found, although Philippine specimens have been compared with males, pupae, and larvae of the New Hebrides series.

A. vigilax vigilax and *v. ludlowi* are commonly confused with *Aedes* (*Aedimorphus*) *vexans*, from which species they can readily be distinguished by their lack of scales on the torus and on the subspiracular area.

Subgenus FINLAYA Theobald

1903. *Finlaya* Theobald, Mon. Cul. 3: 281. Genotype: *poicilia* Theobald (Malaya).

1905. *Popea* Ludlow, Can. Ent. 37: 95. Genotype: *lutea* Ludlow (Philippines).

ADULT: Essentially similar to *Ochlerotatus* but differing in the absence of a distinct basal lobe on the basistyle in most species. Those few species that possess a distinct basal lobe differ from the single Philippine species of *Ochlerotatus* in not having the claspette filament setiform. Male palpi varying from being three-fourths as long as proboscis to exceeding it by the length of the terminal segment; usually similar to *Ochlerotatus* in type but may be simple, straight, and with only a few hairs (at apices of segments III–V). Vertex dorsum and scutellum narrow- or broad-scaled, or with intermediate conditions occurring. Paratergite with or without scales. No lower mesepimeral bristles. Fore and mid tarsal claws toothed in both sexes, in the male the larger claws usually bidentate; hind claws simple in both sexes. *Terminalia:* Basistyle with apical lobe absent; basal lobe usually absent but occasionally weakly formed, or rarely even distinct (*harperi*). Dististyle appendage apical. Mesosome simple. Claspettes present (with a peculiar basotergal lobe in *aureostriatus*), with a prominent, variously shaped filament.

LARVA: Extremely varied, but having in common the following few characteristics: Siphon almost always with an acus at level of pecten teeth. Anal plate without acus, always incomplete, nearly always with spines or spicules on posterior lateral margin. Ventral brush with 8–12 tufts, usually borne on a sclerotized, barred area. Habitat primarily of three types: (1) the water-holding spaces of living plants, (2) tree holes and bamboo stumps, and (3) rock holes in stream beds. One species breeds in the water collected in fallen leaves. A number of species have been occasionally found in artificial containers.

DISTRIBUTION: This is a very large subgenus with approximately 165 named species and subspecies and having a worldwide distribution (absent from the northern rim of the Holarctic Region, however). The subgenus has attained its greatest development in the Oriental Region. Twenty-five named species are at present known from the Philippines.

SYSTEMATICS: On the basis of adult ornamentation characters, this subgenus was divided into eight groups by Edwards (1932: 148). Knight and Marks (in press) modified this system by combining two of the groups and by creating subgroups. Except for Group C, which is confined to the Ethiopian Region, all the groups are represented in the Philippines.

Group A (*kochi*-group). Wings profusely spotted with areas of pale and dark scaling. Represented in the Philippines by *ananae*, *poicilius*, *stonei*, *medleri*, *croceus*, *flavipennis*, and *luteus*.

Group B (*terrens*-group). Hind tarsi with basal and apical white bands on I, a narrow basal band on II, remainder dark. Represented in the Philippines by *melanopterus*.

Group D (*aureostriatus*-group). Scutal marking pattern consisting of 3–5 narrow longitudinal pale lines. Femora and tibiae not lined anteriorly for nearly their whole length. Represented in the Philippines by *aureostriatus*, *saxicola*, *abadsantosi*, *burgosi*, *rizali*, *sherki*, and *jugraensis*.

Group E (*mediovittatus*-group). Similar to Group D except that at least the mid femora and usually also one or more of the tibiae are lined anteriorly with pale scales for nearly their whole length. Represented in the Philippines by *banksi*.

Group F (*alboannulatus*-group). Scutal pale scale pattern not consisting of a set of longitudinal lines. Hind tarsi with basal bands on at least the first three segments. Represented in the Philippines by *harperi*.

Group H (*geniculatus*-group). Tarsi all dark. Represented in the Philippines by *saperoi*, *lacteus*, *laoagensis*, *niveus*, *paradissimilis*, *leucopleurus*, *luzonensis*, and *leucomeres*.

Aedes (Finlaya) ananae Knight and Laffoon

Fig. 4

1946. *Aedes* (*Finlaya*) *ananae* Knight and Laffoon, Trans. Amer. Ent. Soc. 72: 218 (males, females, pupae, larvae). Type locality: Philippines. Osmena, Basey Municipality, Samar (Laffoon). Type: Male (holotype), with associated larval and pupal skins, in U.S.N.M.†

1947. *Aedes* (*Finlaya*) sp. near *poicilius*. Marks, Univ. of Queensland Dept. Biol. Papers 2(5): 34.

DISTRIBUTION: *Specimens examined.* U.S.N.M. Samar: Osmena, Ducong, and Pintanahon, Basey Municipality. Mindanao: 1 male, 2 females, 2 sets of assoc. skins, Lanao, nr. Cotabato-Lanao provincial boundary along the Parang-Malabang Highway, Lanao Prov. (Enke, Hoogstraal). A.N.S.P. Leyte: Lagolago, nr. Baybay; Mt. Lobi, Dagami; Tacloban.

Literature records. Luzon: Lucban, Tayabas Prov. (Marks, 1947: 34).

Unknown outside the Philippines.

DISCUSSION: The only closely related species in the Philippines is *poicilius* (Theobald) which, however, is distinguishable from *ananae* on the basis of the adult and larval characters given in the keys.

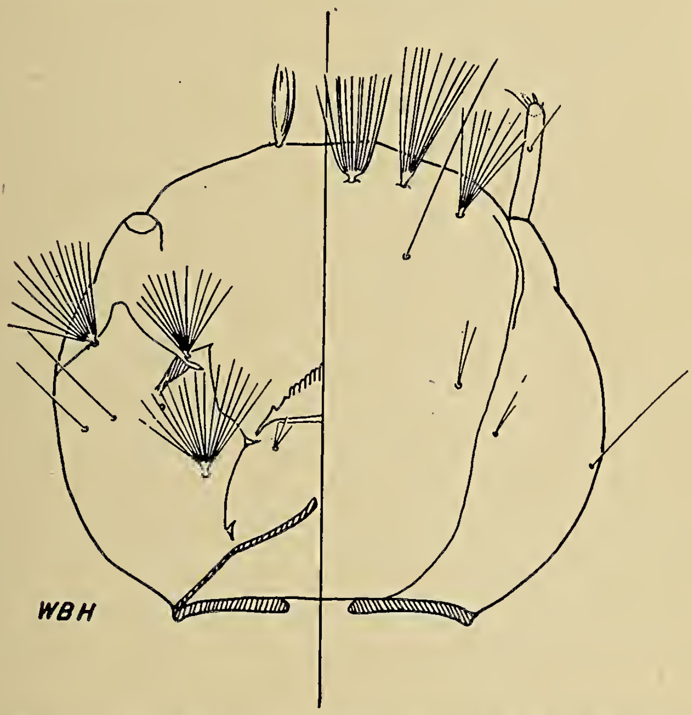

FIG. 4. *A.* (*Finlaya*) *ananae.* Larval head (Samar).

Aedes (Finlaya) poicilius (Theobald)

1903. *Finlaya poicilia* Theobald, Mon. Cul. 3: 283 (female). Type locality: Malay Peninsula. Pulau Jerezak, Penang (Freer). Type: Female (holotype) in B. M.†

1903. *Finlaya poicilipes* Theobald, Mon. Cul. xvii, plate 13. Lapsus.

1904. *Finlaya poialia* Theob. Giles, Jour. Trop. Med. 7: 366. Emendation?

1917. *Aëdes* (*Ochlerotatus*) *poicilia* Theob. Edwards, Bul. Ent. Res. 7: 211. Different combination.

1920. *Aedes* (*Finlaya*) *poicilia* Theobald. Dyar, Ins. Insc. Mens. 8: 183. Different combination.

1926. *Aedes* (*Finlaya*) *kochi* var. *poicilia* (Theo.). Edwards, Bul. Ent. Res. 17: 104. Different combination.

1929. *Aëdes* (*Finlaya*) *poecilia* Theo. Edwards, Not. Ent. 9: 2. Emendation?

1934. *Aëdes* (*Finlaya*) *poecilus* Theobald. Barraud, Fauna Brit. Ind. Dipt. 5: 157. Emendation.

1937. *Aedes* (*Finlaya*) *poicilius.* Bonne-Wepster and Brug, Geneesk. Tijdschr. Ned.-Ind. 74: 44. Emendation.

1944. *Aedes poecilius* (Theobald). Stone and Bohart, Proc. Ent. Soc. Wash. 46: 211. Lapsus in synonymic table.

Adult and larva described by Barraud (1934: 157), Marks (1947:34), and Knight and Laffoon (1946: 221). Stone and Bohart (1944: 211) have keyed the adult and figured the male terminalia, and Brug (1931: 22) and Bonne-Wepster and Brug (1939: 1246) have described the larva.

DISTRIBUTION: *Specimens examined.* U.S.N.M. Luzon: Olongapo, Subic Bay, Zambales Prov.; Los Banos, Laguna Prov.; Camp Stotsenberg and Mabalacat, Pampanga Prov.; Ft. Wm. McKinley, Rizal Prov.; Manila, Manila Prov.; Camp Daraga, Albray Prov.; Nagillian. Leyte: Gabas, Tacloban; Abuyog. Samar: Osmena; Pintanahon; Ducong; Calotans; Catubig. Jinamoc Island. Calicoan Island. Palawan: Iwahig; Balsahan River; Puerto Princesa. Culion: Pilapil. Balabac: Cape Melville. Mindanao: Zamboanga, Pasanonco, and San Ramon, City of Zamboanga Prov.; Parang, Surigao Prov.; Rugagus, Dansalan, Dansalan City Prov. (Enke, Gutierrez). Nanka, Mumungan, Lanao Prov. (Edgar, Enke). Overton, Lanao Prov. (Enke, Gutierrez, Corcega). A.N.S.P. Leyte: Tacloban; Lagolago (nr. Baybay); Palo; Dulag; Valencia. Dinagat: Panamaon. C.A.S. Mindoro: 5 females, with assoc. skins, San Jose (Ross). Leyte: 1 male, Tunga (Ross). C.C.

Luzon: Agoo, La Union Prov. (Franclemont).

Literature records. Negros: Bago and Mailum, Negros Occidental Prov. (Banks, 1906: 990). Luzon: Lucban, Tayabas Prov. (Marks, 1947: 34).

Known outside of the Philippines from Simaloer, Lombok, Java, Sumatra, Borneo, Celebes, Malaya, North Bengal, and Burma.

DISCUSSION: The type of *poicilius* has been examined and found to differ most notably from the Philippine material described here in lacking the basal spot of white scales on the first segment of the fore tarsus (a clear bare spot is present, however). Because of this difference, although admittedly minor in nature, it seems possible that the Philippine material may represent a distinct form. If it does, then it is not confined to the Philippines because in checking for the presence or absence of basal pale scales on I of the fore tarsus on all the female specimens in the British Museum collection it was found that the specimens (three in all) from Lampongs, Sumatra (Shüffner); Batavia, Java (Brug); and Buitenzorg, Java (Paine), all possessed the basal spot of white scales. On the other hand, the specimens (five in all) from Kuala Lumpur, Malaya (Dusham); Kuching (?), Sarawak, Borneo (Moulton); Mt. Korinchi, Sumatra (Robinson and Kloss); and Sandoway, Burma (Barraud), were all similar to the type in lacking the spot.

The type and the specimens from Kuala Lumpur and Kuching also differed from the Philippine specimens in having the lateral scutellar lobes entirely black-scaled except for 2–3 white scales mesally. The specimens from Mt. Korinchi and Buitenzorg had the lateral lobes white-scaled (white basally and dark apically in the Philippine material). However, since the relative amounts of dark and pale scaling of the lateral scutellar lobes are normally somewhat variable in Philippine specimens, this character is probably not of value.

In view of the above-described variations, it would be of great interest to compare the male terminalia of specimens from various portions of the geographical range of *poicilius*. Unfortunately there are no male specimens in either the British Museum or the U. S. National Museum from any locality outside the Philippines. Brug (1934: 513) figured the terminalia from unspecified material (undoubtedly from the Netherlands East Indies, however), but, since he did not include the tergal setal pattern of the basistyle, it is impossible to make a complete comparison with Philippine specimens. However, in the details shown there are no apparent differences.

The only larval descriptions of specimens from elsewhere than the Philippines (and where the collection locality is definitely given) are by Brug (1931: 22, from Javan specimens) and by Edwards (in Barraud, 1934: 158, from Brug's Javan material). Brug described the larva as having head hair 5 with 3 branches and as having a stout elongate spine at the base of the thoracic pleural tufts. Edwards' description differs from that of Brug's in stating that no special spines occur on the plates of the thorax (describes head hair 5 as having 2–3 branches). Whether or not the thoracic spines occur, the Javan specimens are markedly distinct from those of the Philippines on the branching of head hair 5. Three larval specimens in the British Museum from Klakali, R. Bedali, East Java (Thieneman, reared ex *Colocasia*), have been compared (presumably the ones referred to by Edwards in Barraud, 1934) with Philippine specimens. The only notable differences found were: antennal hair double in four of six cases (remainder single), hair 1 (preclypeal spine) single, and head hair 5 with 2–4 branches. Hair 11 of the meso- and metathoracic segments was stoutly spinose as Brug pointed out and as is typical of the Philippine specimens.

Aedes (Finlaya) stonei Knight and Laffoon

1946. *Aedes* (*Finlaya*) *stonei* Knight and Laffoon, Trans. Amer. Ent. Soc. 72: 208

(males, females, pupae, larvae). Type locality: Philippines. Ducong, Basey River, Basey Municipality, Samar (Zolik). Type: Male (holotype), with associated larval and pupal skins, in U.S.N.M.†

DISTRIBUTION: *Specimens examined.* U.S.N.M. Samar: Ducong and Osmena, Basey Municipality. A.N.S.P. Leyte: Mt. Lobi, Dagami.

Unknown outside the Philippines.

DISCUSSION: Distinct from all the other black, yellow, and white species of this group in the Philippines on the basis of the adult and larval characters given in the keys.

Aedes (Finlaya) flavipennis (Giles)

1904. *Finlaya flavipennis* Giles, Jour. Trop. Med. 7: 366 (male, female). Type locality: Philippines. Camp Stotsenberg, Pampanga Province, Luzon (Whitmore). Type: Male and female (cotypes) in B. M.† Male terminalia mounted.

1906. *Finlaya aranetana* Banks, Phil. Jour. Sci. 1: 1001 (male, female). Type locality: Philippines. Mailum, Bago Municipality, and Siya-Siya Peak, Canloan Volcano, 700 m., Negros Occidental Province, Negros (Banks). Type: Male (lectotype) in U. S.-N. M.†

1917. *Aedes* (*Ochlerotatus*) *flavipennis* Giles. Edwards, Bul. Ent. Res. 7: 211. Different combination.

1922. *Aedes* (*Finlaya*) *flavipennis* Giles. Edwards, Ind. Jour. Med. Res. 10: 465. In part. Different combination. Synonymy of *aranetanus.*

1925. *Finlaya aranteana* Banks. Dyar and Shannon, Ins. Insc. Mens. 13: 75. Lapsus.

1944. *Aedes* (*Finlaya*) *aranetanus* (Banks). Stone and Bohart, Proc. Ent. Soc. Wash. 46: 207. Also: Bohart (1945: 56), Knight and Laffoon (1946: 214), Baisas (1946: 30), and Marks (1947: 62). Misidentification.

DISTRIBUTION: *Specimens examined.* U.S.N.M. Luzon: Ft. McKinley, Rizal Prov.; Camp Stotsenberg, Pampanga Prov.; Baguio, City of Baguio Prov.; Olongapo, Subic Bay, Zambales Prov. Leyte. Samar: Bulusao; Osmena. Calicoan Island. Negros (cotypes). Palawan: Puerto Princesa; Iwahig; Bacungan. Busuanga Island: Coron. Balabac: Cape Melville. A.N.S.P. Leyte: Palo; Tacloban. C.A.S. Mindoro: 2 males, with assoc. skins, San Jose (Ross).

Literature records. Luzon: Llavac, Infanta Municipality, Tayabas Prov.; Calauan, Laguna Prov.; Tungkong Manga, San Jose, Bulacan Prov.; Tala Estate of Caloocan, Manila Prov. (Baisas, 1946: 30).

Not definitely known from outside the Philippines.

DISCUSSION: An examination of the type series of this species in the British Museum and comparison with a female cotype of *aranetana*, also in that collection, show Edwards (1922: 465) to have been correct in reducing the latter species to a synonym of *flavipennis.* The one male and two female cotypes of *aranetana* in the U.S.N.M. have also been checked and with the same results.

Edwards (1926: 105; 1928: 52) reported this species from Singapore, but it seems likely that a re-examination of that material will show it to be another species. As pointed out by Knight and Laffoon (1946: 215), the material identified by Brug (1934: 513; 1939: 107) is undoubtedly some other species also. The nature of the subapical scale tuft of the basistyle and of the stem of the claspette as illustrated by him are quite different from either of those structures in *flavipennis.* The female specimen reported from the Solomon Islands by Paine and Edwards (1929: 315) is undoubtedly *solomonis* Stone and Bohart. This specimen is also the basis of the Solomon Islands' record of *flavipennis* by Knight, Bohart, and Bohart (1944: 52).

Occasionally a female specimen of this species is found which is apparently indistinguishable from either *medleri* or *croceus.*

Aedes (Finlaya) medleri
Knight and Laffoon

1946. *Aedes* (*Finlaya*) *medleri* Knight and Laffoon, Trans. Amer. Ent. Soc. 72: 211 (males, females, pupae, larvae). Type locality: Philippines. Jinamoc Island (Medler). Type: Male (holotype), with associated larval skin, in U.S.N.M.†

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Samar: Pintanahon and Osmena, Basey Municipality. Jinamoc Island. Calicoan Island: Ngolos. Mindanao: Zamboanga, City of Zamboanga Prov. A.N.S.P. Leyte: Tacloban. C.A.S. Mindoro: 1 male, 1 set assoc. skins, San Jose (Ross).

Unknown outside the Philippines.

DISCUSSION: As indicated by the adult and larval keys, this species is closely related to *flavipennis*, differing from it only on minor characters. Since the ranges of the two overlap, it is likely that *medleri* is merely a polymorphic form of *flavipennis*.

Aedes (Finlaya) luteus (Ludlow)

1905. *Popea lutea* Ludlow, Can. Ent. 37: 96 (male). Type locality: Philippines. Camp Stotsenberg, Angeles, Pampanga Prov., Luzon (Whitmore). Type: Male, no longer in existence. However, there is a series of specimens in the U.S.N.M. labeled (apparently in Dr. Ludlow's handwriting) "*Popea lutea* Ludl., female and male cotypes, P.I." This is undoubtedly a subsequent type designation and probably the specimens are those reported by Ludlow (1910: 193).†

1922. *Aedes* (*Finlaya*) *flavipennis* Giles. Edwards, Ind. Jour. Med. Res. 10: 465. In part. Synonymized *lutea*.

1944. *Aedes* (*Finlaya*) *flavipennis* (Giles). Stone and Bohart, Proc. Ent. Soc. Wash. 46: 208. Misidentification. Also: Bohart (1945: 57), Knight and Laffoon (1946: 216), Baisas (1946: 30), and Marks (1947: 62).

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Luzon: Camp Stotsenberg, Angeles, Pampanga Prov.; Mt. Makiling, 2000 ft. Leyte: Abuyog. Samar: Guirang and Calotons, on the Basey River, Basey Municipality. Mindanao: Pasanonca, City of Zamboanga Prov.; Mt. Apo, Cotabato Prov., 3000 ft. (Hoogstraal *et al.*). Basilan: Isabela. A.N.S.P. Leyte: Tacloban; Lagolago, nr. Baybay.

Unknown outside the Philippines.

DISCUSSION: It was not until the type of *flavipennis* was studied by the senior author and the results compared with the types of *aranetana* and *luteus* that it was found that *luteus* represents a valid species. Of course, it is possible that the original type male of *luteus* represented some other black, white, and yellow member of this group. However, since this type is no longer in existence and since we have a series of specimens labeled, presumably by Ludlow, as cotypes of *luteus*, it seems justifiable to take our concept of the species from this series.

The male terminalia and the larva of *luteus* are not separable from those of *croceus*.

Aedes (Finlaya) croceus
Knight and Laffoon

1946. *Aedes* (*Finlaya*) *croceus* Knight and Laffoon, Trans. Amer. Ent. Soc. 72: 213 (males, females, pupae, larvae). Type locality: Philippines. Santa Rita, Olongapo, Subic Bay, Zambales Prov., Luzon (Rozeboom). Type: Male (holotype), with associated larval and pupal skins, in U. S.-N. M.†

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Luzon: Santa Rita, Olongapo, Subic Bay, Zambales Prov. C.A.S. Mindoro: 2 females, assoc. skins, San Jose (Ross).

Unknown outside of the Philippines.

DISCUSSION: Closely related to *luteus*, the male terminalia and the larva apparently being inseparable. Because of this close similarity, it seems quite likely that *croceus* is either a subspecies of *luteus* or else a polymorphic form of it. However, insufficient material is available at present to settle the status of these forms.

Aedes sp., near **medleri** and **flavipennis**

There is a single male specimen in the U.S.N.M. which is similar to *medleri* in having the proboscis largely dark-scaled except for a median band, and to *flavipennis* in having the subapical tergal scale tuft of the basistyle long and pale; but it differs from either in that this scale tuft arises in a scattered elongate area extending from the row of stout setae on the basal one-third of the tergal aspect to near the apex of the basistyle, instead of from a compact circular area as in *medleri* and *flavipennis*. This specimen, which was reared from pandanus by J. L. Laffoon, is from Cape Melville, Balabac Island (VI–1945). Whether or not this specimen represents a distinct species can only be determined when more material is available from that area. Deposited in U.S.N.M. as *Finlaya* Sp. 40.

Aedes (Finlaya) melanopterus (Giles)

Figs. 5, 6

1904. *Finlaya melanoptera* Giles, Jour. Trop. Med. 7: 367 (female). Type locality: Philippines. Camp Stotsenberg, Angeles, Pampanga Prov., Luzon (Whitmore). Type: Female (holotype) in B. M.†

1914. *Popea palawanensis* Ludlow, Psyche 21: 30 (female). Type locality: Philippines. Puerto Princesa, Palawan. Type: Female (holotype) in U.S.N.M.†

1917. *Ochlerotatus* (*F.*) *melanopterus* Giles. Edwards, Bul. Ent. Res. 7: 214. Different combination. Synonymized *palawanensis*.

ADULT: A black and white species with prominent white scutal markings. Hind tarsi with incomplete basal and apical bands on I, a narrow basal band on II, remaining segments all dark. King and Hoogstraal (1946: 311) have partially described the male and larva.

Male. Wing length 3.0–3.5 mm. *Head:* Proboscis dark-scaled. Palpus approximately equal to the proboscis in length; dark-scaled; V shorter than IV, the hairs on the apex of III and along IV–V rather sparse, segments IV–V not curved and only very slightly downtilted. Torus bare; some dark scales on the first flagellar segment of antenna. Vertex completely covered with broad white scales, some narrow pale scales on the nape, a band of pale upright-forked scales on the nape (may appear brownish in some lights) and a few scattered anteriorly on the dorsum. *Thorax:* Scutum covered with narrow scales, these white (frequently with a yellowish tinge) except for a transverse band of dark scales at the level of the paratergite (interrupted medially by white scales and with a posterior extension on either side of the prescutellar area) and for an area of dark scales in the postero-lateral corner of the scutum; dorso-central bristles present, acrostichals and prescutellars absent. Scutellum with a patch of narrow white scales on the mid lobe, lateral lobes with a very few hair-like brownish scales. *Apn* with broad white scales; *ppn* with a small dorso-anterior patch of broad white scales. The following pleural areas each with a patch of broad white scales: propleural, paratergite (on the under surface), dorsal sternopleural, medio-posterior sternopleural, and upper mesepimeral (an oblique band extending from the anterior margin in the vicinity of the dorsal sternopleural patch to the dorsal hair tuft). *Legs:* Fore femur with anterior surface dark except for a few basal white scales (one specimen had a dorso-apical white patch), posterior surface marked with a broad pale area from near base to beyond middle; mid femur with anterior surface dark, marked by a ventral white area from near base to beyond middle and by a separate apical white area, posterior surface pale-scaled with a basal dark area and another just beyond the middle that has a dorsal extension nearly to the apex (this area variable); hind femur pale-scaled, marked anteriorly and posteriorly with a basal and a subapical dark area. Fore tibia with posterior surface pale except for extreme apex, this pale scaling extending onto the anterior surface apically; mid tibia dark except for an apical pale area (some dark scales present on the extreme apex, however); hind tibia dark. Fore tarsus dark; mid tarsus with a broad basal band and an incomplete apical white band on I, a dorso-basal spot on II; hind tarsus with incomplete dorso-basal and apical white bands on I, a narrow incomplete basal band on II, III–V dark. Fore and mid tarsal claws unequal, the larger bidentate, the smaller unidentate; hind claws equal, simple. *Wings:* Dark-scaled, may be a few pale scales at the base of the costa. Halter knob dark-scaled. *Abdomen:* Tergites I, VI, and VII with lateral white bands; II–III with a baso-lateral white area (sometimes forming a nearly complete basal band on III), IV–VII with narrow basal white bands, IV–VII with the median dark scales somewhat erected. Sternites dark-scaled, a basal patch of white scales present on most of them; III–VII with prominent medial tufts of dark elongate erected scales. *Terminalia:* Basistyle without lobes, a prominent patch of setae on basal half of mesal-tergal surface and another medially on mesal-sternal surface. Mesosome simple, slightly expanded apically. Claspette filament expanded subapically in lateral view. Lobes of ninth tergite interrupted.

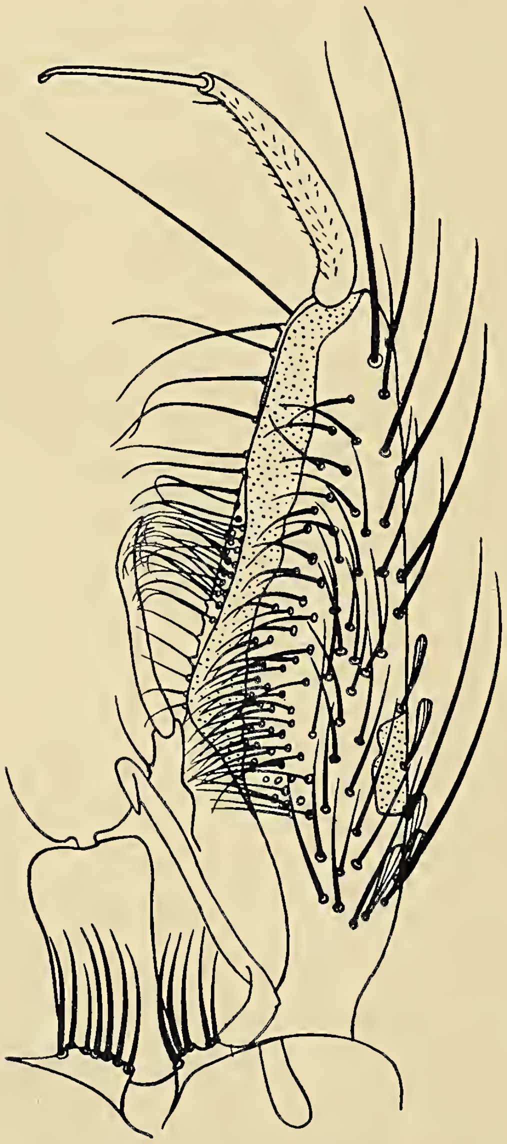

FIG. 5. *A.* (*Finlaya*) *melanopterus.* Male terminalia (Luzon).

The male from Palawan had the transverse dark scutal band broadly interrupted medially.

Female. Wing length about 3.5 mm. Differs from male mainly as follows: Palpus approximately one-fifth as long as the proboscis. Torus with fine dusky hair-like scales medially. Vertex dorsum with broad dark scales (may be a very few pale ones medially), a patch of narrow pale scales anteriorly on the median line and some also on the nape, a line of pale scales along the eyes, and scattered dark upright-forked scales; lateral area with broad white scales. Scutum with narrow scales, dark except for a large anterior area of white scales, a white area before the wing base, and before and along the prescutellar area. Scutellar mid lobe with narrow pale scales, narrow dark scales intermixed laterally; lateral lobe with a few narrow pale scales. Tarsal claws equal, fore and mid each unidentate, hind simple. Tergites dark, IV–VII with a small baso-median white spot, VIII with a broad basal white band, lateral aspect marked as in male.

LARVA. *Head:* Antenna smooth; antennal hair single, inserted at apical one-third. Mouth brush with comb-like tips. Preclypeal spine single, stout. Hair 4 with 4–7 branches, very small; 5 and 6 single; 7 with 2–5; 8 with 2–3; 9 with 2–4; 12 with 4–7; 13 with 1–2; 14 with 1–3; 15 with 4–7; 17 and 18 single or double; 20 with 1–3. Mentum with 7–10 lateral teeth. *Thorax:* Some of the meso- and metathoracic hairs stellate-type. Prothoracic hair 0 with about 7–10 branches, small, stellate; hair 1 with 2–4 branches; 2 single; 3 with 5–7. Mesothoracic hair 9 with 6–7 branches, very long, stout; 10 and 12 single, long, stout; 11 with 1–3 minute branches. Metathoracic hair 9 with 5–7 branches; 10 and 11 as on mesothorax; 12 single, greatly reduced in size. *Abdomen:* Some of the dorsal and ventral hairs stellate-type. Dorso-lateral hairs of I and II with 3–4 branches. Lateral hairs of I–VI double, rarely triple. Pentad hair 1 with 3–6 branches; 3 with 9–10; 5 with 4–6. Comb with about 28 to 35 scales in a patch, scales apically broadened and completely fringed. Siphon brownish, detached acus present, index 2.4–3.3; 18–29 pecten teeth, each with a strong ventral denticle near middle and a fine fringe from denticle to base; siphon hair tuft inserted beyond middle and shortly before the end of the line of pecten teeth, with 5–9 plumose branches; dorso-lateral valve hair approximately as long as siphon diameter at apex; the two ventrolateral valve hairs shorter than the valve in length. Anal plate narrowly incomplete, posterior margin heavily spined both above and below *lh*; *lh* with 1–2 branches; *isc* with 4–6; ventral brush of 10 tufts, all but the basal 1–3 tufts arising from a heavily sclerotized, connected barred area, each tuft with 4–8 branches. Anal gills tapered from base, dorsal pair slightly longer than ventral pair and 1.25–1.5 times longer than the anal plate.

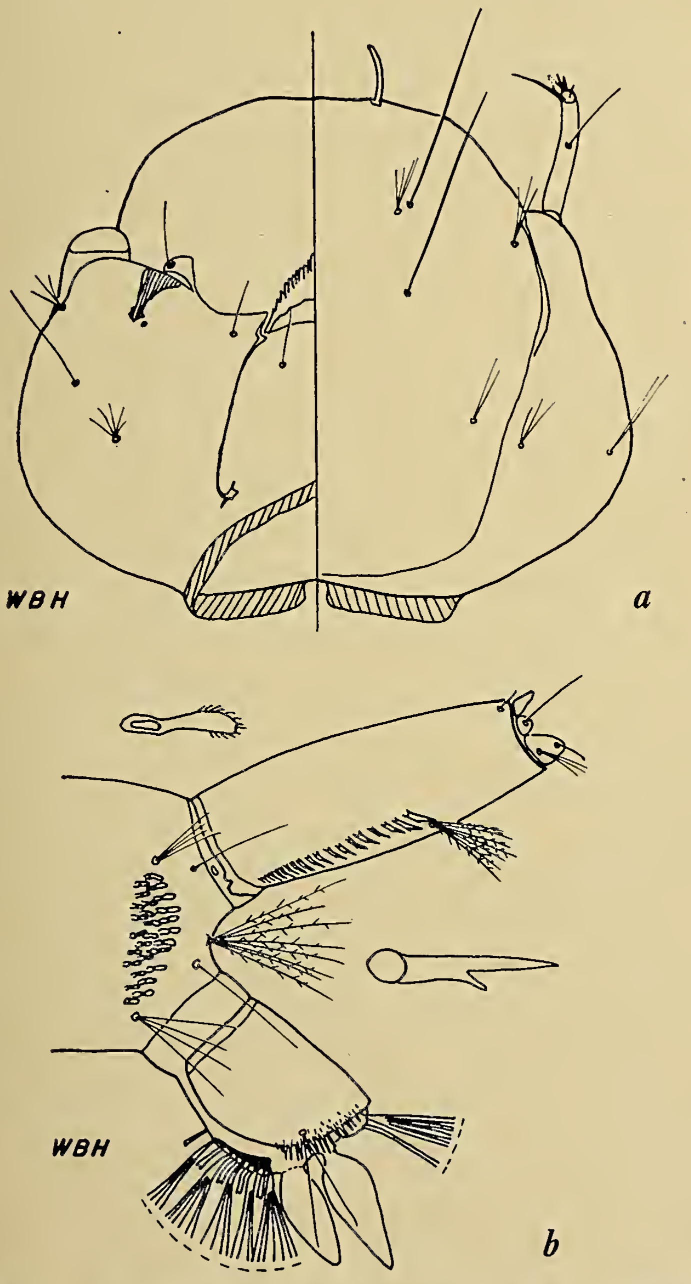

FIG. 6. *A.* (*Finlaya*) *melanopterus*. Larva. *a*, Head (Busuanga); *b*, terminal segments (Leyte).

Four larvae from Tacloban, Leyte, differed from the above series in having the anal gills almost bud-like and the abdominal hairs much less developed. The specimen from Palawan and two of those from Tacloban had a curious medial lateral bulge on the preclypeal spine.

BIONOMICS: The adults were not encountered in nature. All the larval material of this species was taken from various types of tree holes, except for the collection from Busuanga, which was found in a water-holding enameled refrigerator.

DISTRIBUTION: *Specimens examined.* R. K. L. (10 males, 19 females, 23 sets assoc. skins, 1 larva). Luzon: Olongapo, Subic Bay, Zambales Prov. (Rozeboom). Palawan: Balsahan River (Johnson, Laffoon). Culion: Pilapil (Laffoon, Fitzgerald). Busuanga: Coron (Fitzgerald). A.N.S.P. Leyte: Tacloban (Roberts). C.A.S. Mindoro: San Jose (Ross).

Literature records. Palawan: Puerto Princesa (Bohart, 1945: 57).

Unknown outside the Philippines.

DISCUSSION: This species, which is the sole representative of Group B in the Philippines, is closely related to *plumiferus* King and Hoogstraal from New Guinea.

Aedes (**Finlaya**) **aureostriatus** (Doleschall)
Fig. 7

1857. *Culex aureostriatus* Doleschall, Nat. Tijdschr. Ned.-Ind. 14: 385 (female). Type locality: Amboina. Type: Non-existent.

1924. *Finlaya greeni* (Theo.) var. *Ranarana* Barraud, Ind. Jour. Med. Res. 11: 850 (male, female). Type locality: India. Karwar, N. Kanara (Barraud). Type: Location not known.

1934. *Aëdes* (*Finlaya*) *greeni* (Theobald) var. *kanaranus* Barraud. Barraud, Fauna Brit. Ind., Dipt. 5: 185. Emendation. Edwards, p. 442 in above reference, questioningly synonymizes *kanaranus*.

ADULT: Scutum with a linear pattern of yellow lines. Hind tarsi with basal and apical markings on I–IV, V largely or all pale dorsally in female.

Male. Wing length about 2.4 mm. *Head:* Proboscis dark. Palpus about three-fourths as long as proboscis; similar in type to that of *saxicola;* all dark. Vertex dorsum with a median longitudinal area of narrow yellow scales (may be a few broad yellow scales marginally), an anterior submedian area of broad dark scales, and a lateral area of broad white scales which extends across the lateral surface, nape with a band of pale upright-forked scales. *Thorax:* Scutum with a pattern of broad yellow-scaled lines as follows: a longitudinal median line to prescutellar area where it forks to the posterior margin (this line of scales is parted medially), a complete longitudinal submedian line, a line or area along lateral margin from the beginning of the subdorsal line to over the wing base, a transverse line from lateral margin along anterior fossa to the subdorsal line, remainder of scutum dark-scaled. Scutellar mid lobe with narrow yellow scales medially, broadened dark scales laterally; lateral lobes with narrow yellow scales. *Apn* with broad pale scales; *ppn* with narrow yellow scales, some broadened scales may occur ventro-posteriorly. The following pleural areas each with a patch of broad white scales: propleural, subspiracular, prealar, dorsal sternopleural, medio-posterior sternopleural, and mesepimeral. *Legs:* Fore and mid femora anteriorly dark, a small basal pale area and a few scattered pale scales along the ventral margin. Hind femur pale anteriorly, with a subapical dark band that extends basally along the anterior margin. Tibiae dark, a ventral area of pale scaling basally. Fore tarsus dark. Mid tarsus with a basal band on I, some indefinite pale scaling over the junction of I and II. Hind tarsus with basal and apical bands on I–III, a basal band on IV, complete only on I and at the base of II, V dark or else palish above. *Wings:* Dorsally dark-scaled. Halter knob dark-scaled. *Abdomen:* Tergites dark-scaled, I with a lateral white band, II–VI with baso-lateral silvery-white spots, a few basal white scales medially on some of the segments. Sternites with basal silvery bands. *Terminalia:* Tergal surface of basistyle with a group of elongate bristles apically and a group of short ones basally; below this basal setose area and

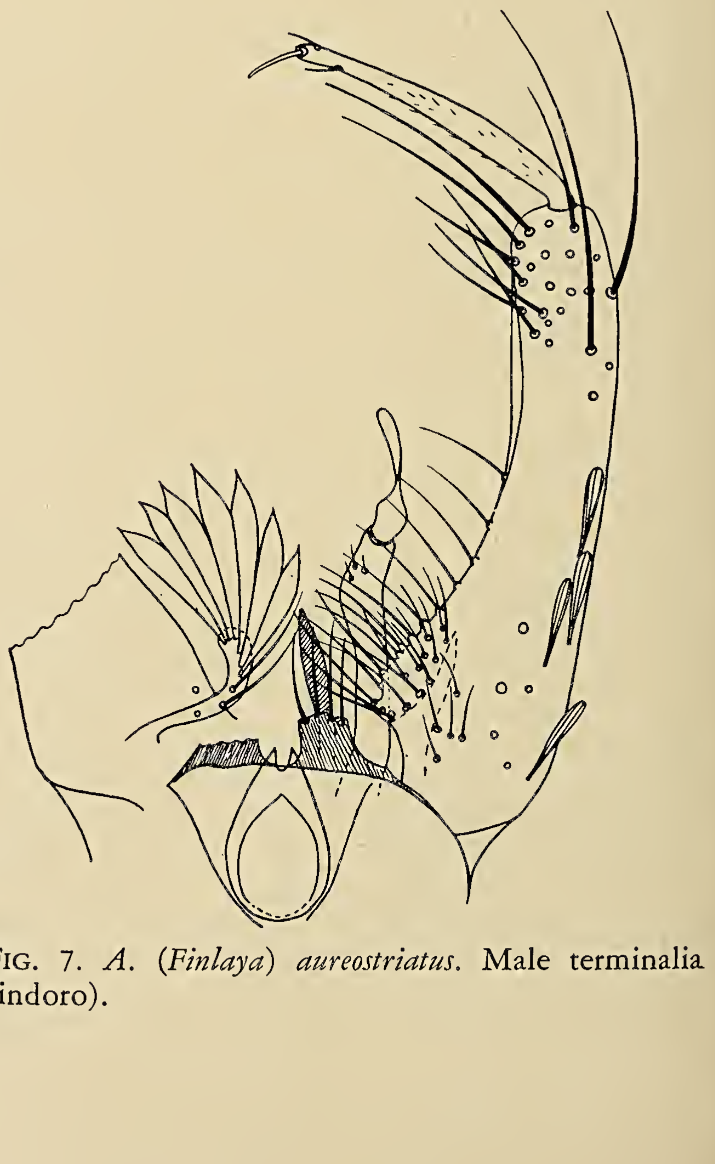

FIG. 7. *A.* (*Finlaya*) *aureostriatus.* Male terminalia (Mindoro).

tergally attached to the base of the claspette is a slender elongate detached lobe that bears a curving line of blade-like scales (omitted from right side of figure but shown isolated on left side); inner tergal margin with a line of stiff setae from base to near middle. Claspette filament a twisted blade-like structure.

Female. Wing length about 2.5 mm. Differing from the male as follows: Palpus about one-fifth as long as proboscis, dark. Torus not scaled. Hind tarsal V with dorsal pale scaling (probably for whole length but difficult to make out on the single specimen at hand). Tergite VII with a complete basal band.

The female from Culion differs from the above specimen as follows: Median scutal line not parted down the middle, the anterior portion of the submedian line and the line along the anterior fossa largely obsolete, all of the scutal markings more reduced in size. Hind tarsus with basal and apical banding on I–IV, V definitely white-scaled dorsally for its whole length. Complete basal bands on tergites III–VII.

LARVA: Apparently identical to the larva of *leucopleurus* except for the following points: Head hair 5 (present on one side only) with 5 branches. Lateral hairs on abdominal segments I and II are stouter, and the lateral hair on II is the same length as the lateral hair on I. All ventral brush tufts arising from a connected barred area. A detached acus is present on the anal plate of the single specimen examined.

BIONOMICS: The adults were not encountered in nature. Both the larval collections were from tree holes.

DISTRIBUTION: *Specimens examined.* R.K.L. Culion Island: 1 female, Pilapil (Laffoon, Fitzgerald). C.A.S. Mindoro: 1 male, 1 female, 1 set assoc. skins, San Jose (Ross).

Outside of the Philippines this species is known from Sumatra, Java, Celebes, Kabaena, Alor, Soembawa, Timor, Ceram, Amboina, Dutch New Guinea, and India.

DISCUSSION: Not previously known from the Philippines.

The identification of these specimens is based upon a comparison with a series of specimens from Hollandia, New Guinea, of what is believed to be *aureostriatus.* However, as the type of *aureostriatus* is non-existent, this latter identification can only be regarded as provisional. The New Guinea specimens differ slightly as follows: The upright-forked scales of the vertex are brown, the lateral scutellar lobes have brown narrow scales, and the abdominal tergal bands are incomplete except occasionally on VI–VII, the lateral larval hair on abdominal segment I is stouter, and the lateral larval hair on segment II is double, stout, and long (rather than single, short, and slender). The male terminalia appear to be completely similar. The scutal markings are exactly similar to those of the female specimen from Culion.

Aedes (*Finlaya*) *aureostriatus* var. *greeni* (Theobald), known from India, Ceylon, Assam, Sumatra, and Java, is apparently separable from the type species only on the basis of the suffused nature of the scutal pale scale pattern. It is possible that the Mindoro specimens should be considered this variety. The type of *greenii*, which has been seen by us, has the upright-forked scales yellow, the lateral scutellar scales brown, and complete abdominal bands on tergites III–VI.

On the basis of the remarks by Edwards (in Barraud, 1934), *kanaranus* is here regarded as a synonym of *aureostriatus.* The location of the type of this form is at present unknown.

Aedes (*F.*) *okinawanus* Bohart from Okinawa is very closely related to *aureostriatus*, apparently differing only slightly on details of the male terminalia.

Aedes (Finlaya) saxicola Edwards

1908. *Hulecoeteomyia fluviatilis* Leicester (nec Lutz, 1904), Cul. Malaya, p. 111 (male, female). Type locality: Malay Peninsula. Ulu Gombak (Leicester). Type: Non-existent.

1922. *Aedes* (*Finlaya*) *saxicola* Edwards, Ind. Jour. Med. Res. 10: 466 (nom. nov.).
1923. *Finlaya greigi* Barraud, Bul. Ent. Res. 13: 406 (male, female). Type locality: Assam. Haflong, Cachar Hills (Barraud). Type: Male, female (cotypes) in B. M.†
1932. *A.* (*F.*) *saxicola* Edwards, Gen. Insect., Fasc. 194: 151. Synonymy of *greigi.*
1946. *Aedes* (*Finlaya*) *rizali* Banks. Baisas, Phil. Bur. Health Mon. Bul. 22: 21. Misidentification.

Adult and larva have been described by Barraud (1934: 191) and Knight (1947*b*: 628).

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Palawan: Puerto Princesa. Irahuan and Balsahan Rivers.

Outside of the Philippines it is known from Malaya, Java, Siam, and India.

DISCUSSION: There are four larval specimens from Palawan deposited in the U. S. National Museum as *Finlaya* sp. No. 42 that possibly represent a species near to *saxicola.* They have been described by Knight (1947*b*: 647). The differences between these larvae and that of *saxicola* apparently consist entirely of the possession by the former of more heavily branched hairs. This difference, although striking in appearance, is a rather minor one. Consequently, they may represent only a polymorphic form of *saxicola*, rather than a new species.

Aedes (Finlaya) **abadsantosi** Baisas

1946. *Aedes* (*Finlaya*) *abadsantosi* Baisas, Phil. Bur. Health Mon. Bul. 22: 25 (male, female, pupa, larva). Type locality: Philippines. Llavac, Infanta Municipality, Tayabas Prov., Luzon (Baisas). Type: Male (holotype), with associated larval and pupal skins, in the Philippine Bureau of Health, Manila. Terminalia separated.

Adult and larva also described in detail by Knight (1947*b*: 641).

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Samar: Osmena and Sohoton Springs, on Basey River. Mindanao: San Ramon, Zamboanga Prov. A.N.S.P. Leyte: Lagolago, nr. Baybay, Dagami. Samar: Osmena.

Literature records. Luzon: Upper Molawin Creek, Los Banos Agr. Coll., Laguna Prov. Type series, Llavac, Infanta Municipality, Tayabas Prov. (Baisas, 1946: 25).

Unknown outside the Philippines.

DISCUSSION: This and the following three species (*burgosi*, *rizali*, and *sherki*) are all very closely related and probably represent either a polymorphic or a polytypic species. Quite likely, *jugraensis* can also be included within this complex. However, the available collection data are too meager to solve this problem.

Aedes (Finlaya) **burgosi** Baisas
Fig. 8

1946. *Aedes* (*Finlaya*) *burgosi* Baisas, Phil. Bur. Health Mon. Bul. 22: 27 (males, females, larvae, pupae). Type locality: Philippines. Titunod Creek in Kolambugan, Lanao, Mindanao (Guinto). Type: Male (holotype), non-existent. Paratypes in the Philippine Bureau of Science, Manila, and in the U.S.N.M.

DISTRIBUTION: Known definitely only from the type series.

DISCUSSION: From the discussion of this species by Knight (1947*b*: 643), it would appear that *burgosi* probably represents only a polymorphic form of *abadsantosi.* The adults are not separable on external characters. The male terminalia differ only in that *burgosi* possesses 12–30 bristles on each lobe of the ninth tergite, whereas *abadsantosi* has 4–10 bristles on each lobe. The larva of *burgosi* differs from *abadsantosi* on the greater number of branches of some of the hairs, and on the pecten not having any of the teeth distinctly out of line ventrally.

If the series of specimens from Mt. Apo, Davao, Mindanao, described by Baisas (1946:

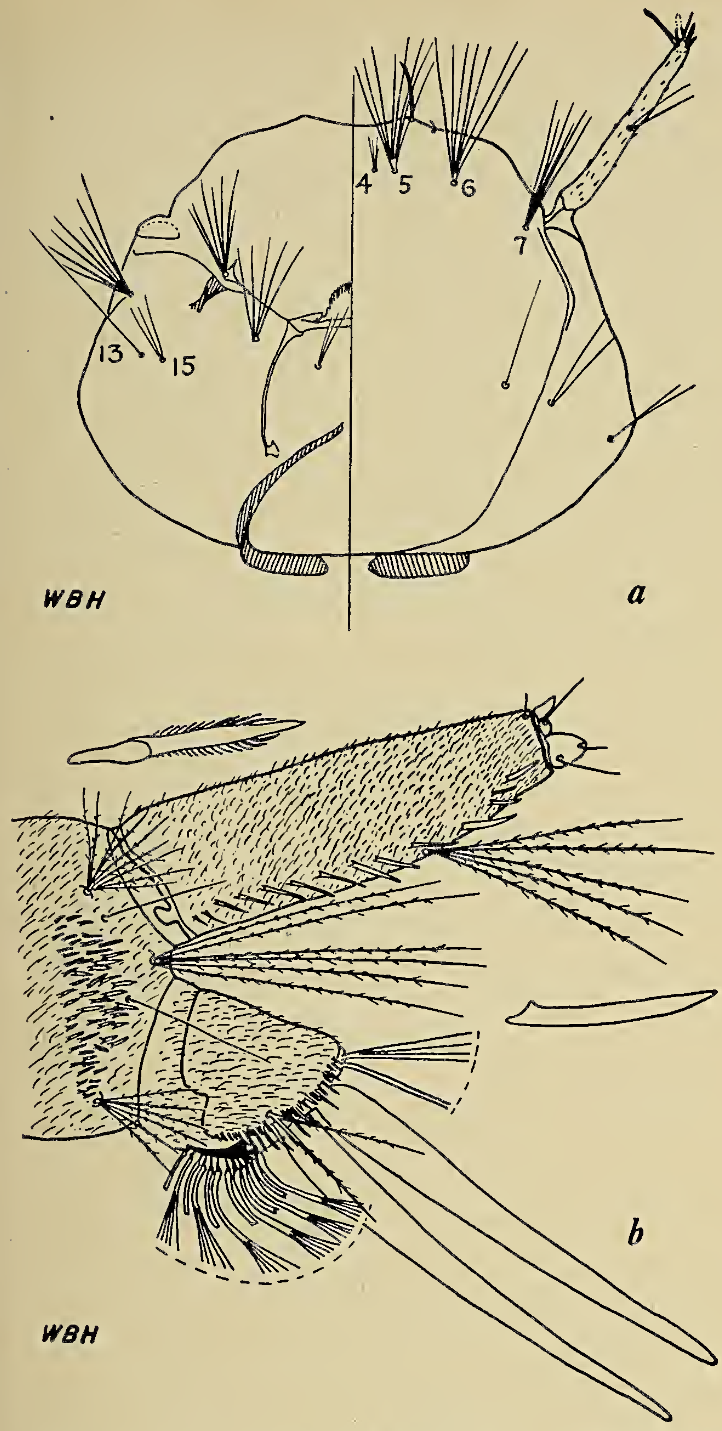

FIG. 8. *A.* (*Finlaya*) *burgosi.* Larva (Mindanao). *a*, Head; *b*, terminal segments.

28) are considered to be *burgosi*, even the male terminalic difference disappears because these specimens have a range of only 9–11 bristles on each ninth tergite lobe.

Aedes (Finlaya) rizali (Banks)

1906. *Culex rizali* Banks, Phil. Jour. Sci. 1: 999 (2 females). Type locality: Philippines. Volcano Canlaon, Mt. Siya-Siya, at altitude of 760 m., Negros Occidental Prov., Negros Island (Banks). Type: Female (holotype), non-existent.

1922. *Aedes* (*Finlaya*) *rizali* Banks. Edwards, Ind. Jour. Med. Res. 10: 466. Different combination.

DISTRIBUTION: Known only from the type series.

DISCUSSION: The status of this species has been discussed by Knight (1947*b*: 644). As stated above, *rizali* has apparently not been retaken since Banks' type series was collected; nor have any additional notes ever been published on the types (destroyed during World War II). However, it must be very closely related to *abadsantosi* and *burgosi*, the only significant difference apparent from a study of the type description being the complete or nearly complete tergal bands of the latter two species (always complete on VIII). The extent of the tergal markings is subject to so much variation in this group of species that it is even possible that this character does not offer a valid distinction. Consequently, until material is again collected from the type locality of *rizali* its exact status will probably remain undetermined. With only the type description to go on, this species is also not separable from *jugraensis.*

The novotype material designated for *rizali* by Baisas (1946: 21) is cospecific with *saxicola.*

Aedes (Finlaya) sherki Knight

1947. *Aedes* (*Finlaya*) *sherki* Knight, Ann. Ent. Soc. Amer. 40: 645 (males, females, pupae, larvae). Type locality: Philippines. Baguio, City of Baguio Prov., Luzon (Rozeboom). Type: Male (holotype), with associated larval and pupal skins, in the U. S. N. M.†

DISTRIBUTION: Known only from the type series. However, the type series is the result of four separate collections (and all by different people) so that the species must be well established at Baguio.

DISCUSSION: This species is only definitely distinct from the preceding three by the presence of a basal white patch or band on segment IV of the hind tarsus. No definite character for the separation of the larva of *abadsantosi* and the larva of *sherki* has been found. All characters examined seemed to show sufficient intergradation to render them useless for positive identification. Consequently, it seems likely that *sherki* represents, at the most, only a subspecies of *abadsantosi*.

As pointed out in the type description, the larva is polymorphic.

Aedes (**Finlaya**) **jugraensis** (Leicester)

Fig. 9

1908. *Helecocteomyia jugraensis* Leicester, Cul. Malaya, p. 109 (male, female). Type locality: Malaya. Jugra (Leicester). Type: Male, female (cotypes), non-existent. Note: Error in generic name spelling.

1922. *Aedes* (*Finlaya*) *jugraensis* Leicester. Edwards, Ind. Jour. Med. Res. 10: 466. Different combination.

Adult described by Knight (1947*b*: 647) and larva by Edwards and Given (1928: 343), both from Malayan material. The following larval description is based upon two Philippine specimens and constitutes the first record of this species in the Philippines. No adults were taken.

LARVA: *Head:* Antenna slender, a few small spicules present; antennal hair double, inserted just beyond middle. Mouth brush with prominent comb-like tips. Hair 4 double, small; 5 and 6 with 3–4 branches; 7 with 3–5; 8 single; 9 double; 12 with 3–4; 13 single; 14 with 1–2; 15 with 3–4; 17 with 3–8; 18 with 1–2; 20 with 2–4; hairs 4, 5, and 6 are all in a straight line. Mentum with 11–13 lateral teeth. *Thorax:* Prothoracic hair 1 with 3 branches; 2 with 1; 3 with 3; all rather large and borne together on a sclerotized plate. A stout spine occurs at the base of the pleural hair tufts. Hair 1 of the mesothorax single, stout, darkly pigmented; hair 7 of metathorax with 4 branches, each short, very stout, darkly pigmented, and barbed. *Abdomen:* Dorsolateral hairs on I and II double. Lateral hairs on I and II single; on III to VI double, once triple. Pentad hair 1 with 2–3 branches; 2 and 4 single; 3 with 4–7; 5 with 2–4. Comb with 14 to 19 large scales in a patch or double row, each scale pointed and fringed laterally. Segment VIII and anal segment ventral to anal plate pilose. Siphon incomplete basally, with an attached acus, index 2.4–3.0; 9–11

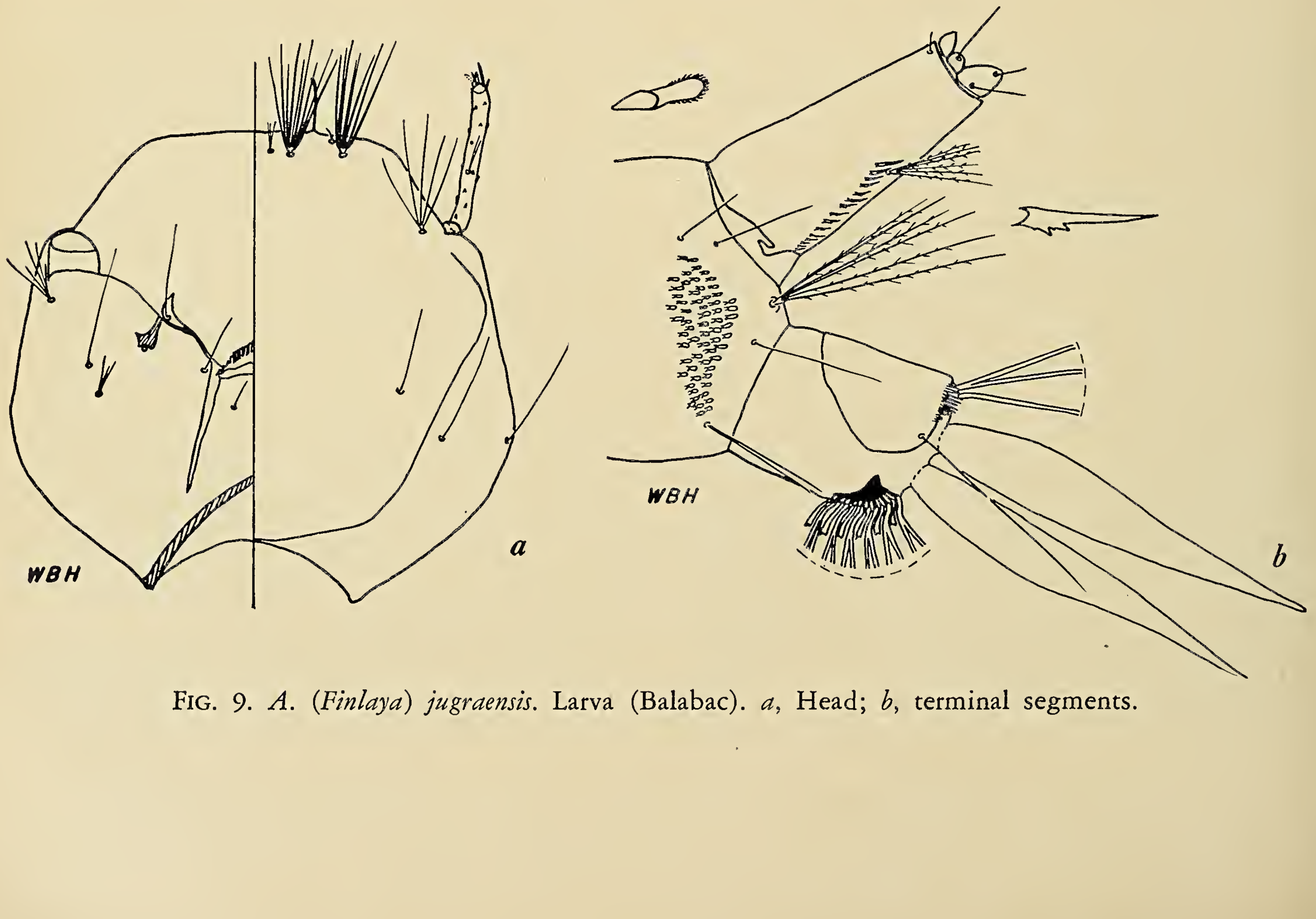

FIG. 9. *A.* (*Finlaya*) *jugraensis.* Larva (Balabac). *a*, Head; *b*, terminal segments.

pecten teeth in an even row, none beyond siphon tuft, each tooth with 1 or 2 ventral denticles; siphon hair tuft with 3–5 branches. Anal plate broadly incomplete, with a row of short spines on posterior margin; *lh* single, stout; *isc* with 3–6 branches, *osc* single; ventral brush of 12 tufts, each tuft with 2–6 branches, sometimes one tuft off the barred area basally; barred area joined laterally by a sclerotized line. Anal gills long, tapering, subequal, about 3.0 times longer than anal plate.

DISTRIBUTION: *Specimens examined.* R.K.L. Balabac Island: 2 larvae, Cape Melville (Johnson).

Outside of the Philippines this species is known only from Malaya.

DISCUSSION: Since the male terminalia of *jugraensis* has not been described, it is impossible to discuss its exact relationship with the closely related group of four species just preceding (*abadsantosi*, *burgosi*, *rizali*, and *sherki*). However, there is no question but that it is closely related to this group.

Aedes (Finlaya) spp., near **abadsantosi**

In the British Museum collection there is a female specimen from the Philippines that possibly represents an unknown species. It closely resembles *abadsantosi* except that the anterior portion of the postspiracular scale patch consists of narrow yellowish scales and does not extend to the ventral margin of the spiracle. All of the abdominal tergites are dorsally dark except for a complete basal band on VIII. The specimen has the following data: Mt. Mupo, Dansalan, Mindanao, 28–III–1920 (Dr. A. Moore).

In the collection of the Academy of Natural Sciences of Philadelphia, there is a female specimen, Lagolago, Leyte (H. R. Roberts), with the postspiracular scales similar to those of the above specimen but differing in having the tergites with complete basal bands.

Also, in the U. S. National Museum there is a male specimen, with associated larval and pupal skins, which cannot be separated from *abadsantosi* except on male terminalia. The claspette filament is slender and tubular instead of being laterally flattened (this is utterly unlike anything known in this group), and there are 11–13 hairs on each of the ninth tergite lobes. The data for this specimen are: San Ramon, Mindanao (Knight and Laffoon), reared from rock hole in hill stream, 17–IX–1945.

Aedes (Finlaya) **banksi** Edwards
Figs. 10, 11

1906. *Hulecoetomyia pseudotaeniata* Giles. Banks, Phil. Jour. Sci. 1: 986. Misidentification of specimens from Luzon.

1922. *Aedes* (*Finlaya*) *banksi* Edwards, Ind. Jour. Med. Res. 10: 270 (males, females). Type locality: Philippines. Montalban, Rizal Prov., Luzon (Banks). Type: Male (holotype) in B. M.† Terminalia mounted.

ADULT: Characterized by the pattern of narrow sharply defined yellow lines on the scutum, by the median pale-scaled longitudinal line along the anterior surface of the mid femora, and by the hind tarsi having basal and apical bands on segments I–IV and with V all white dorsally.

Male. Wing length about 2.8 mm. *Head:* Proboscis dark. Palpus slightly shorter than the proboscis; dark, basal half of V white-scaled dorsally; a number of hairs apically on III and laterally along IV–V. Vertex dorsum with a median longitudinal stripe of narrow pale scales (some also present on the nape), remainder broad-scaled, the dorsal portion being dark-scaled and marked with a longitudinal white band medially, a line of pale scales along the ocular margin; the lateral surface of vertex with broad pale scales; dark upright-forked scales scattered over the dorsum. *Thorax:* Scutum covered with narrow dark scales, marked with sharply defined thin longitudinal lines of narrow yellowish scales as follows: A median line that forks at the prescutellar space, a short subdorsal line beginning near the anterior margin and extending posteriorly to the level of the fossae, a line curving mesally along the fossae and then extending straight back to the posterior margin of the scutum, a short line above the wing base, and an even shorter line or patch on the lateral margin just above the paratergite; dorso-central, acrostichal, and prescutellar bristles present. Scutellum with small broad dark scales on the mid lobe, some pale scales may be present basally, lateral lobes with sparse narrow pale scales. *Apn* with broad pale scales; *ppn* with a line of narrow-curved pale scales along dorsal margin, broadened dark scales centrally, and a small patch of broadened pale scales ventrally. The following pleural areas each with a patch of broad pale scales: Propleural, subspiracular, postspiracular, paratergite, sub-prealar, dorsal sternopleural, medio-posterior sternopleural, and mesepimeral. *Legs:* Fore femur with anterior surface dark except for a thin longitudinal white line very near to the ventral margin, mid femur similar except the line is median, hind femur similar except the line is broader and is near to the dorsal margin for at least a portion of its course. Fore tibia with an apical pale band, mid tibia may have a broken white-scaled anterior line, all of the tibiae with a short ventro-basal area of pale scaling. Fore tarsus dark, mid tarsus with a basal white band on I and usually some apical pale scales; hind tarsus with basal and apical bands on I–IV (apical pale area on IV incomplete ventrally), V all white on dorsal surface. Fore and mid tarsal claws unequal, the larger bidentate, the smaller unidentate; hind tarsal claws equal, simple. *Wings:* Dark-scaled, a short subbasal pale area on the costa. *Abdomen:* Tergite I with a lateral band of pale scales, II with a small medio-basal pale spot, III–VI with basal white bands. Sternites with basal white bands. *Terminalia:* Basistyle without basal and apical lobes, lateral surface heavily scaled (omitted in figure). Claspette appendage elongate, slender, only slightly broadened in lateral view.

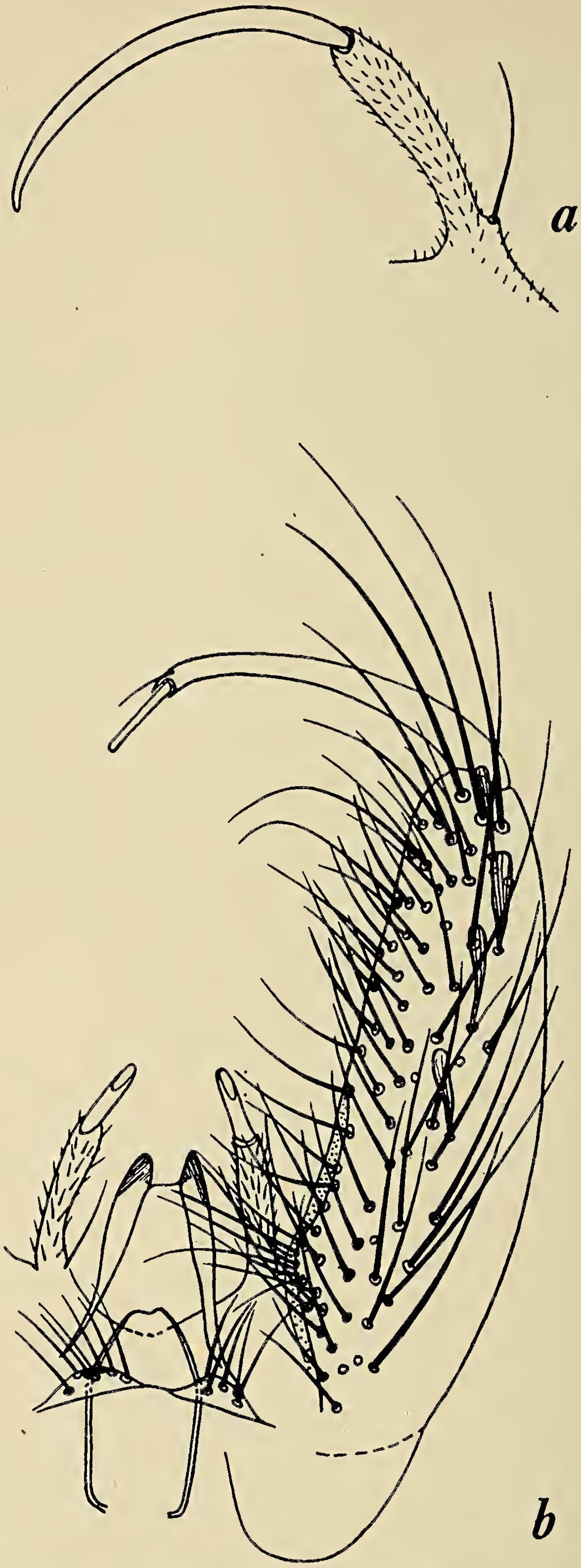

FIG. 10. *A.* (*Finlaya*) *banksi.* Male terminalia. *a*, Lateral aspect of claspette (Samar); *b*, terminalia (Mindanao).

Female: Differs from male chiefly as follows: Palpus approximately one-fourth as long as the proboscis, apex pale-scaled, a small subbasal pale patch usually present. Torus with pale scales medially. Fore tarsus with a narrow

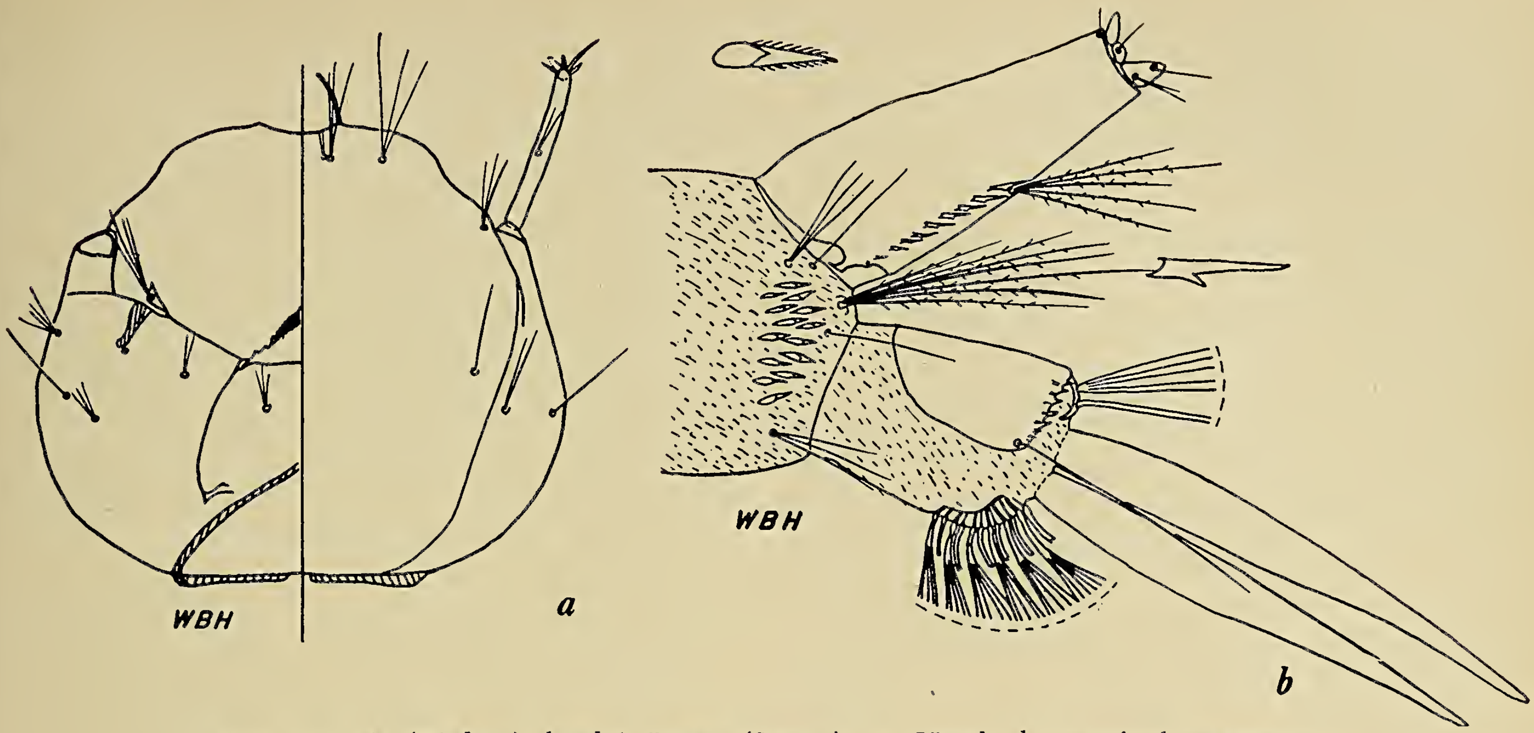

FIG. 11. *A.* (*Finlaya*) *banksi.* Larva (Samar). *a*, Head; *b*, terminal segments.

basal pale band on II, may be some apical pale scaling on I; mid tarsus with small basal bands on I–IV and apical pale scaling on I–II. Tarsal claws equal, fore and mid each unidentate. Tergites II–VI and VIII with basal bands, VII with a baso-lateral white patch, and sometimes a small medio-basal spot.

The series of specimens from Mindoro and Jolo differ slightly from the Samar series in having hind tarsal segment IV all white dorsally (was very narrowly interrupted on two specimens). Also, the subbasal white patch on costa is frequently obsolete dorsally or reduced to a line of scales on the anterior margin only.

LARVA: *Head:* Antenna spiculated, antennal hair double (occasionally single), inserted before middle. Mouth brushes with prominent comb-like tips. Hair 4 small with 1–5 branches; 5 with 7–12; 6 with 7–11; 7 with 3–6; 8 single; 9 single or double; 12 with 3–6; 13, 14, and 17 single; 15 with 3–5; 18 and 20 single or double. Mentum with 12–15 lateral teeth. *Thorax:* Prothoracic hairs 1 and 2 single, hair 3 with 2–3 branches; this group borne together on a small sclerotized plate. Mesothoracic hair 9 with 5–6 branches; hairs 10 and 12 single, stout; hair 11 single, very small. Metathoracic hair 9 with 4 branches; 10 single, stout; 12 greatly reduced. *Abdomen:* Dorso-lateral hairs on I and II double. Lateral hair on I single or double; on II to V double; on VI single. Pentad hair 1 with 1–3 branches; 2 and 4 single; 3 with 4–8; 5 with 1–4. Comb of 40–61 scales in a patch, the scales rounded and fringed apically and laterally. Siphon with acus narrowly attached, rarely detached, index 1.2 to 2.0; 12–25 pecten teeth in a straight row with ventral denticles; siphon hair tuft with 4–11 branches, length less than width of siphon. Anal plate incomplete, with a patch of spines on the posterior lateral margin; *lh* single, stout; *isc* double, *osc* single; ventral brush with 11–13 tufts on a barred area, the tufts with 2–3 branches; barred area connected on each side to a sclerotized plate. Anal gills subequal, broadest at base and tapering sharply to a long slender point; dorsal gills 2.7–3.4 times longer than the anal plate.

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Luzon: 4 larval skins, 1 larva, Baguio, City of Baguio Prov. 8 larvae, Burgos, Mountain Prov. R.K.L. Samar: 4 males, 20 females, 14 sets assoc. skins, 2 larvae, Kenamatayan River, Osmena (Knight, Laffoon, Rozeboom). Mindanao: 2 males, 9 females, 8 sets assoc. skins, San Ramon (Johnson, Laffoon, Knight). Basilan: 1 male, 3 females, 3 sets assoc. skins, 4 kilometers from Isabela (Knight). C.C. Luzon: 8 males, 38 females, 6 larvae, Antamok, Mountain Prov. (Franclemont).

Literature records. Luzon: Gorge Camp, Manila waterworks, Rizal Prov. (Banks, 1906: 986).

Unknown outside the Philippines.

DISCUSSION: This species, which is the sole representative of Group E in the Philippines, is closely related to *pseudotaeniatus* (Giles) of India. However, *pseudotaeniatus* is distinct from *banksi* in having hind tarsal segment V all dark. Other minor color variations also occur. Male terminalia and larvae are very similar.

Aedes (Finlaya) **harperi** Knight

1948. *Aedes* (*Finlaya*) *harperi* Knight, Proc. Ent. Soc. Wash. 50: 4 (males, females, pupae, larvae). Type locality: Philippines. Zig-Zag Pass, Subic Bay, Zambales Prov., Luzon (Rozeboom and MacMillan). Type: Male (holotype) in U. S. N. M.† Terminalia mounted.

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Type series. Luzon: Zig-Zag Pass, Olongapo, and Matain, all in Subic Bay area, Zambales Prov.

Unknown outside the Philippines.

DISCUSSION: This species, which is the sole representative of Group F in the Philippines, is closely related to *stevensoni* (Barraud) of India. However, *stevensoni* differs as follows: vertex without a white median area; only the first three hind tarsal segments banded (sometimes a trace of a marking on IV); female tergites without complete bands except VIII, which is all white; and the basal white-scaled area on costa very small. The larva is unknown.

Aedes (Finlaya) **niveus** (Ludlow)
Fig. 12

1903. *Stegomyia niveus* Ludlow, Jour. N. Y. Ent. Soc. 11: 139 (female). Type locality: Philippines. Oras, Samar. Type: Female (lectotype) in B. M.†

1905. *Scutomyia nivea* Ludlow. Theobald, Gen. Insectorum, Cul., p. 19. Different combination.

1910. *Stegomyia pseudonivea* Theobald, Mon. Cul. 5: 176 (male). Type locality: Andaman Islands (Lowis). Type: Male (allotype) in the B. M.† Terminalia mounted.

1917. *Aëdes* (*Ochlerotatus*) *niveus* Ludl. Edwards, Bul. Ent. Res. 7: 211. Different combination.

1923. *Finlaya nivea* (Ludl.). In part. Barraud, Ind. Jour. Med. Res. 11: 480. Different combination.

1931. *Aedes* (*Finlaya*) *niveus* (typus) (Ludlow). Brug, Arch. Hydrobiol. Suppl.-Bd. 9: 25. First association of male terminalia and larva. Sumatra and Bali.

1932. *A.* (*F.*) *niveus* Ludlow. Edwards, Gen. Insectorum, Cul., Fasc. 194, p. 154. Synonymy of *pseudonivea* Theobald, 1910 (male only). Pointed out that the female of *pseudonivea,* described by Theobald (1905: 75), is a distinct species.

Adult and larva are described by Barraud (1934: 208) and Knight (1946: 278).

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Luzon: Batangas, Batangas Prov.; Subic Bay, Zambales Prov. Samar: Oras. Palawan: Puerto Princesa, Irahuan River, and Tacburos. Busuanga: 1 larva, Coron (Fitzgerald). A.N.S.P. Leyte: Tacloban (Roberts). C.A.S. Mindoro: 3 males, 3 females, San Jose (Ross).

Literature records. Of the Philippine records given by Bohart (1945: 58), only that for Oras is definitely this species.

From outside the Philippines there are apparently reliable literature records from South Bengal, Ceylon, Andaman Islands, Sumatra, Bali, Java, Flores, Malacca, Borneo, and Siam. The records from China and Japan are probably not for this species.

DISCUSSION: This species and the following three are members of the *niveus* subgroup

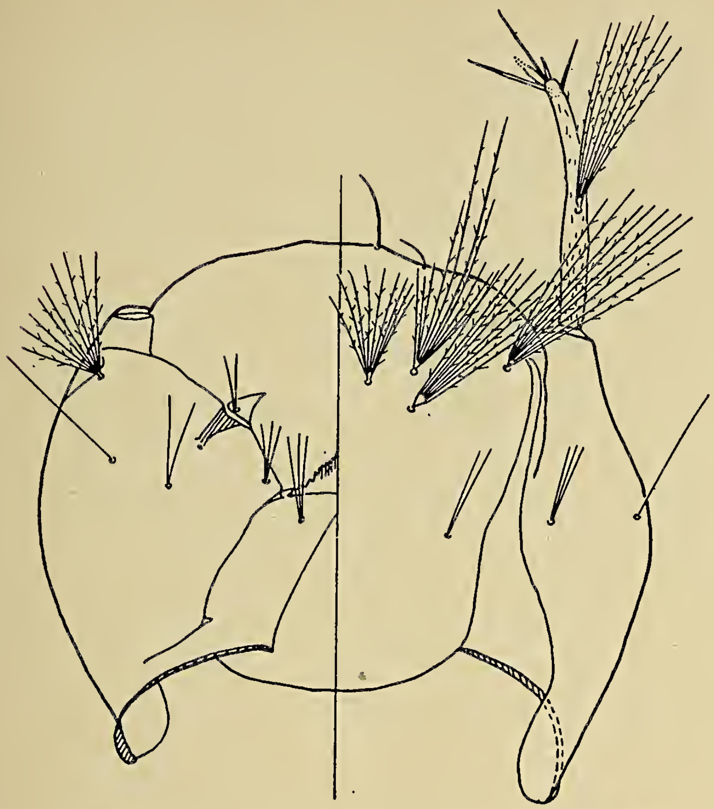

FIG. 12. *A.* (*Finlaya*) *niveus.* Larval head (Palawan). Drawn from exuvium.

of Group H. The *niveus* subgroup, consisting at present of 12 valid species and subspecies, is distributed throughout the Oriental Region. Although insufficient data are available at present, it appears to be at the superspecies stage in development.

Since the appearance of the treatment of the *niveus* subgroup by Knight (1946), the senior author has had the opportunity of seeing the lectotype of *niveus* and the male allotype of *pseudonivea* in the British Museum. The terminalia of the latter was separated and examined. Both specimens were found to be typical *niveus* as treated here.

Knight (1946: 278) described the female scutum as having the anterior two-thirds solidly white-scaled. However, in a number of the specimens from Leyte and in one of the three females from Mindoro listed in the distribution section above, the white scutal patch is interrupted posteriorly for as much as three-fourths of its depth by a median extension of the posterior dark-scaled area.

Apparently the female of this species is not definitely separable from that of *lacteus.* However, it is possible that the palpi are shorter in *lacteus* (about one-eighth length of proboscis in few observed cases) than they are in *niveus* (one-fifth to one-sixth as long).

Aedes (Finlaya) lacteus Knight

1946. *Aedes* (*Finlaya*) *lacteus* Knight, Jour. Wash. Acad. Sci. 36: 275 (male, female, larvae). Type locality: Philippines. Cape Melville, Balabac Island (Laffoon and Johnson). Type: Male (holotype) in U. S. N. M.† Terminalia mounted.

DISTRIBUTION: Known only from the type series of one male, one female, and two larvae. A female specimen in the U.S.N.M. from Parang, Mindanao (Paullus), is possibly this species, but in the absence of a male positive identification is not possible.

DISCUSSION: This species possibly represents only a polymorphic form of *niveus,* being closely similar to it in the adult and larval stages.

Externally, the male is not definitely separable from that of either *niveus* or *laoagensis.*

Aedes (Finlaya) saperoi Knight
Fig. 13

1946. *Aedes* (*Finlaya*) *saperoi* Knight, Jour. Wash. Acad. Sci. 36: 271 (males, females, larvae). Type locality: Philippines. Subic Bay, Luzon (Zedeck and Zolik). Type: Male (holotype), with associated larval and pupal skins, in U. S. N. M.† Terminalia mounted.

DISTRIBUTION: *Specimens examined.* U.S.N.M. Luzon: Subic Bay, Zambales Prov. Mindanao: 4 females, 3 sets assoc. skins, Pasanonco, Zamboanga (Laffoon). 3 males, 3 females, Kisante, Kidapawan, Cotabato Prov. (Enke, Corcega).

Unknown outside the Philippines.

DISCUSSION: The Pasanonco specimens listed above were treated by Knight (1946: 280) as an unidentified species. The later

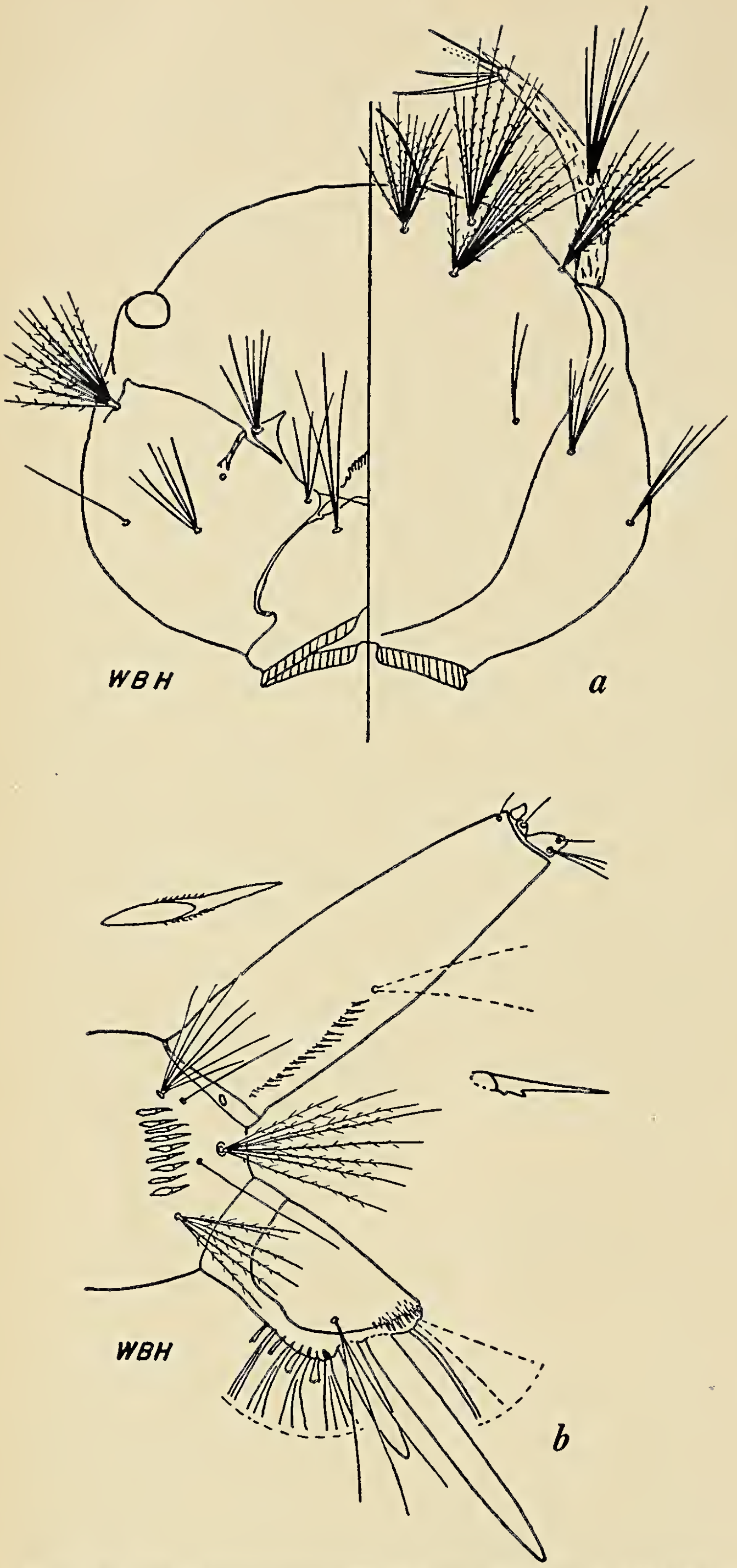

FIG. 13. *A.* (*Finlaya*) *saperoi.* Larva (Culion). *a*, Head; *b*, terminal segments.

opportunity of seeing male terminalia from the Cotabato series showed all the Mindanao specimens to be *saperoi*, differing from the previously known specimens in having the apical dark area of the hind femur broadly complete on the anterior aspect.

A re-examination of the larval specimen (Fig. 13) from Culion Island, tentatively named as *albolateralis* (Theobald) by Knight (1946:279), has shown it to be equally similar to *saperoi*. Because of this finding, *albolateralis* has been dropped from the Philippine species list. However, the Culion specimen is included in the larval key under the name *albolateralis* to call attention to the possibility that this species may still be found to occur in the Philippines.

This species is very similar to *laoagensis*.

Aedes (Finlaya) laoagensis Knight

1946. *Aedes* (*Finlaya*) *laoagensis* Knight, Jour. Wash. Acad. Sci. 36: 276 (males, female, larva). Type locality: Philippines. Laoag, Ilocos Norte Prov., Luzon (Hoogstraal). Type: Male (holotype) in U. S. N. M.† Terminalia mounted.

DISTRIBUTION: *Specimens examined.* U.S.-N.M. Luzon: Laoag, Ilocos Norte Prov.; Baguio, City of Baguio Prov.; Subic Bay, Zambales Prov.; San Fernando; Rizal Prov.; Laguna Prov.; Tayabas Prov.

Unknown outside the Philippines.

DISCUSSION: Distinguishable from the other species of the *niveus* subgroup in the Philippines on the divergence of the scutal white-scaled area from the lateral margin over the paratergite in the female. Although the terminalic characters differ slightly, the male does not differ externally from *saperoi*. The larva is not distinguishable with certainty from that of *saperoi* except possibly on the number of branches of the antennal hair tuft and on the spiculation of the posterior margin of the anal plate.

Aedes (Finlaya) paradissimilis Rozeboom

1946. *Aedes* (*Finlaya*) *paradissimilis* Rozeboom, Jour. Parasit. 32: 587 (males, females, pupae, larvae). Type locality: Philippines. Cape Melville, Balabac (Johnson and Laffoon). Type: Male (holotype), with associated larval and pupal skins, in U. S.-N. M. Terminalia mounted.

DISTRIBUTION: *Specimens examined.* C.A.S. Mindoro: 4 males, 4 females, 9 sets assoc. skins, San Jose (Ross).

Literature records. Leyte: Lagolago, Baybay; Libjo, Dinagat Island; Diit River, Tacloban. Calicoan Island (nr. Samar): N'golos. Palawan: Irahuan River. Balabac Island: Cape Melville (Rozeboom, 1946: 588).

Unknown outside the Philippines.

DISCUSSION: This species and the following three are members of the *dissimilis* subgroup of Group H. The *dissimilis* subgroup, consisting at present of five valid species and subspecies and of one unrecognized name (*leucomeres*), is distributed over Malaya, India, China, and the Philippines. The members of this subgroup are all extremely similar and probably constitute either a polytypic species or a superspecies.

A. paradissimilis appears to be most closely related to *dissimilis* (Leicester) from India and Malaya, but is stated by Rozeboom (1946: 590) to differ from that species in larval characters.

Aedes (Finlaya) **leucopleurus** Rozeboom

1946. *Aedes* (*Finlaya*) *leucopleurus* Rozeboom, Jour. Parasit. 32: 588 (male, pupa, larvae). Type locality: Philippines. Irahuan River, Palawan (Johnson and Laffoon). Type: Male (holotype), with associated larval and pupal skins, in U. S. N. M. Terminalia mounted.

DISTRIBUTION: Known only from the type series. Palawan: Irahuan River. Culion Island: Pilapil. This series is divided between the U.S.N.M. and the B.M.

DISCUSSION: Distinguishable from *paradissimilis*, only in the larval stage, by the following characters: Head hairs 4, 5, and 9 and prothoracic hair 0 each with a greater number of branches; posterior process of mandible truncate; lateral hair on abdominal segment II only about one-half the length of that on I; and apical fringe of comb scales without a stout central spine.

The female is unknown.

Aedes (Finlaya) **luzonensis** Rozeboom

1946. *Aedes* (*Finlaya*) *luzonensis* Rozeboom, Jour. Parasit. 32: 589 (males, females, pupae, larvae). Type locality: Philippines. Subic Bay, Zambales Prov., Luzon (MacMillan). Type: Male (holotype), with associated larval and pupal skins, in the U. S. N. M. Terminalia mounted.

DISTRIBUTION: *Specimens examined.* C.A.S. Mindoro: 2 males, 4 females, 2 sets assoc. skins, 1 larva, San Jose (Ross).

Literature records. Type series. Luzon: Subic Bay, Zambales Prov.

Unknown outside the Philippines.

DISCUSSION: The adult of this species is separable from those of *paradissimilis* and *leucopleurus* by the presence of 2–3 hairs of about equal size at the apex of the claspette of the male terminalia. The larva differs mainly in having the lateral hair of abdominal segments I and II paler, slenderer, and more branched, and of segments III–V more branched; and on the structure of the pecten teeth.

Aedes (Finlaya) **leucomeres** (Giles)

1904. *Stegomyia leucomeres* Giles, Jour. Trop. Med. 7: 367 (female). Type locality: Philippines. Camp Stotsenberg, Pampanga Prov., Luzon (Whitmore). Type: Female (holotype) in B. M.†

This species is known only from the type female. This specimen has been examined and found to be somewhat damaged. The antennae, fore and hind legs, and one mid leg are entirely missing, and the scutum is rubbed bare over the median area. The type was compared with paratype females of *paradissimilis* and *luzonensis*. It was found similar to *luzonensis* in having two pale setae on the upper part of propleuron but differed in having a short median spot on the mid femur (rather than one that is one-half the length of the femur), and in having this spot extending onto the ventral aspect. The type differed from *paradissimilis* only in having two, rather than one, propleural bristles.

Since the members of the *dissimilis* subgroup cannot be adequately distinguished in the female, the true relationship of *leucomeres* is unknown at present.

As Rozeboom (1946: 590) pointed out, the two anterior scutal spots described by Giles from the type are actually the silvery scale patches on *ppn*. No scutal markings are apparent now on the type.

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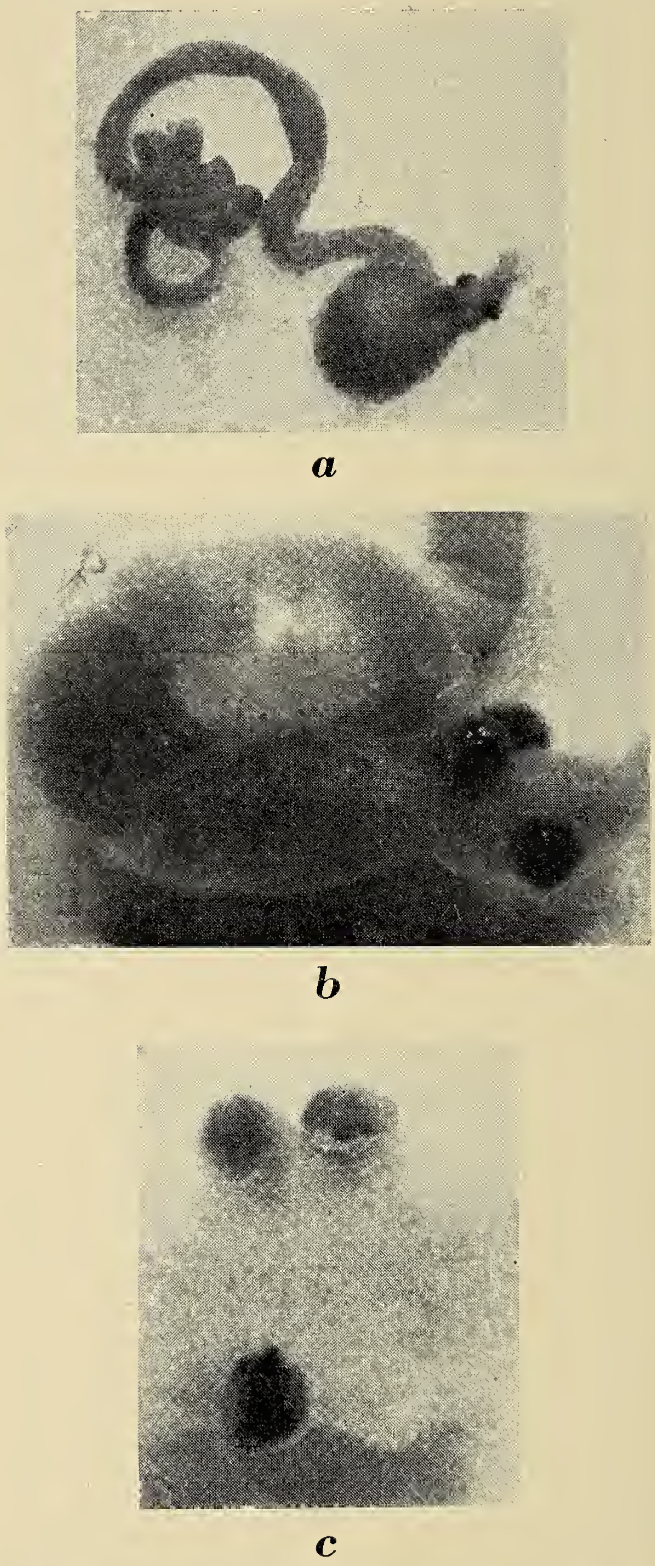
Notes on *Tetrameres* sp. (Nematoda, Spiruroidea) Parasitic in the English Sparrow in Hawaii

LEO KARTMAN[1]

WHILE ENGAGED by the University of Hawaii Agricultural Experiment Station in 1947, the writer participated in a study of wild birds as possible carriers of poultry parasites. During the course of this work incidental observations were made on a species of *Tetrameres* parasitic in *Passer domesticus*. A more thorough study of this parasitic nematode was then contemplated, but it now appears that such a project may not be feasible. Since the parasite in question is undoubtedly a new species[2] and some worker may wish to describe it, it seems desirable that these notes be recorded to serve as a basis for future work.

In her treatise on bird nematodes, Cram (1927) listed 15 species of *Tetrameres* from various birds, but none in the English sparrow. A related parasite, *Microtetrameres inermis*, was listed as having the sparrow as a definitive host, but as far as can be determined no other information on sparrow parasites in the nematode family Tetrameridae is available in the literature.

The roundworm genus *Tetrameres* is of both academic and economic interest. The nematode presents a striking sexual dimorphism in that the mature female loses its typical filiform shape after invading the glands of the proventriculus and assumes a globular appearance (Fig. 1). Also, unlike the male, the female becomes blood-red in color. It is during the invasion of the stomach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b

c

FIG. 1. Three females of *Tetrameres* sp. shown protruding from the outer proventricular wall of the English sparrow. *a*, Position of parasites in relation to gizzard and intestine; *b*, enlargement to show globular appearance of females; *c*, one female entirely free of the enveloping proventricular tissue, and other two partly imbedded.

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[1] Federal Security Agency, U. S. Public Health Service, Helena Malaria Investigations Station, Helena, Arkansas. Manuscript received November 15, 1950.

[2] In a personal communication (1948), Dr. E. E. Wehr, U. S. Department of Agriculture, Bureau of Animal Industry, expressed the opinion that ". . . the specimens from the sparrow do not closely fit the description of any known species . . . ."

glands that the most severe clinical symptoms and even death of young birds may occur. Both males and females have been noted to feed on blood, and Cram (1931) pointed out that *T. americana* causes emaciation and droopiness in young chicks.

The primary objective of the present observations was to determine if the sparrow *Tetrameres* is infective to chickens. Additional biological data on this parasite have also been recorded.

MATERIALS AND METHODS

English sparrows were obtained by shooting them out of trees on the poultry farm at the University of Hawaii Agricultural Experiment Station. These birds were immediately dissected. Seasonal records on parasite incidence were thus obtained from February, 1947, to March, 1948. In some cases an examination of individual proventricular glands was made and the number of male and female parasites per gland was noted.

Adult female *Tetrameres* were removed from the proventriculus and macerated in a small dish in a drop of physiological saline. Bits of this material were fed to grasshoppers (*Oxya chinensis* and *Conocephalus saltator*). The individual hosts were subsequently dissected to check upon their experimental infections; no infected controls were found. The grasshoppers were maintained in a small screened cage and provided with various grasses from their natural habitat. Infected grasshoppers showing third stage (infective) larvae of the parasite were fed to young chicks by forcing the whole grasshopper into the crop with a long forceps.

DATA AND DISCUSSION

The seasonal incidence of *Tetrameres* sp. in the sparrow is shown in Table 1. These data indicate male and female infected hosts about equal in number and no apparent significant fluctuation in percentage of infection throughout the season. Nevertheless, the obvious conclusion is not justified since the age of the parasite and of the host is unknown, thus precluding any inferences on the rate of parasitic transfer from the intermediate to the definitive host. Cursory inspection indicated that the majority of female parasites were

TABLE 1

SEASONAL INCIDENCE OF *Tetrameres* SP. IN *Passer domesticus* FROM UNIVERSITY OF HAWAII AGRICULTURAL EXPERIMENT STATION

DATE	NO. BIRDS	NO. BIRDS INFECTED				NO. PROVENTRICULAR GLANDS INVADED		
		♀	♂	Total	%	Min.	Max.	Mean
2-8-47	12	3	1	4	33.3	1	10	3.3
3-1-47	11	2	2	4	36.3	1	2	1.5
4-3-47	20	5	4	9	45.0	1	3	1.8
6-5-47	12	1	1	2	16.6	1	2	1.5
7-8-47	15	1	2	3	20.0	1	2	1.5
9-10-47	19	3	1	4	21.0	1	4	2.0
10-20-47	20	1	4	5	25.0	1	10	4.2
11-14-47	18	3	4	7	38.8	1	6	1.9
12-14-47	25	4	4	8	32.0	1	4	1.5
1-16-48	20	4	2	6	30.0	1	9	3.0
2-10-48	15	2	3	5	33.3	1	6	2.0
3-21-48	20	7	3	10	50.0	1	8	2.1
Totals	207	36	31	67	22.2	1	10	2.1

TABLE 2

INCIDENCE OF *Tetrameres* SP. IN INDIVIDUAL GLANDS OF PROVENTRICULUS OF INFECTED SPARROWS

BIRD	NO. GLANDS INVADED	NO. ADULT		NO. ♂ PER GLAND			NO. ♂ IN PROVENTRICULAR LUMEN
		♀	♂	Min.	Max.	Mean	
1	1	1	4	–	–	4.0	0
2	10	10	18	0	4	1.8	8
3	1	1	2	–	–	2.0	0
4	1	1	2	–	–	2.0	0
5	1	1	1	–	–	1.0	0
6	2	2	1	0	1	0.5	3
7	2	2	4	0	4	2.0	0
8	1	1	0	–	–	0.0	1
9	1	1	1	–	–	1.0	2
10	1	1	4	–	–	4.0	0
11	3	3	1	0	1	0.3	0
12	3	3	3	0	2	1.0	0
13	2	2	3	1	3	1.5	1
14	2	2	1	0	1	0.5	2
15	1	1	3	–	–	3.0	0
16	1	1	1	–	–	1.0	2
17	2	2	3	0	3	1.5	0
Totals	35	35	52	0	4	1.4	19

mature. Table 1 also presents some data on the number of proventricular glands invaded in the parasitized birds, the average number of invaded glands per bird being 2.1.

Individual parasitized proventricular glands were examined and it was found that no more than one female nematode per gland was the rule. The number of males varied from zero to four, with an average of about 1.4 per gland for all glands examined. Additional male worms were found in the proventricular lumen (Table 2). It should be noted that, unlike other *Tetrameres* species heretofore studied, the present form eventually reaches the outside stomach wall subsequent to its invasion of the gland from within the lumen. When a sparrow is first dissected, these globular, bright red female worms can be seen surrounded by the delicate intima of the outer stomach wall. They exert considerable pressure on this membrane, for a slight cut with a scalpel results in immediate expulsion of the female (see Fig. 1).

The mature female is nothing more than a sac of uterine coils filled with eggs, many of which are embryonated. These embryonated eggs have polar filaments about 12μ in length, and the eggs themselves are about 52μ long by 30 μ wide (Table 3).

Although the grasshoppers used here may not be the actual intermediate hosts in nature, the sparrow *Tetrameres* completed development in them. The parasite underwent two molts in these hosts—from the first to second, and second to third larval stages. The third larval stage was typically filariform and is presumed to be the infective stage for the vertebrate host. These third stage larvae were

TABLE 3

MEASUREMENTS IN MICRONS OF 25 EMBRYONATED EGGS OF *Tetrameres* SP. TAKEN FROM FEMALE UTERI

SIZE	MIN.	MAX.	MEAN
Length	50	55	52.2
Width	29	33	30.4
Length of polar filament	9	15	12.0

TABLE 4

DEVELOPMENT OF *Tetrameres* SP. IN *Oxya chinensis* AND *Conocephalus saltator*

LARVAL STAGE	NO. LARVAE MEASURED	LENGTH IN μ			WIDTH IN μ			MEAN LENGTH IN μ	
		Min.	Max.	Mean	Min.	Max.	Mean	Esophagus	Tail
1........	18	196	375	266.6	16	32	21.0	126.4	48.3
2........	5	388	555	473.6	28	37	33.0	170.4	70.8
3........	7	740	891	830.1	40	45	42.0	pre- 133.5 post- 169.4	105.5

found loosely encysted along the dorsal body wall of the grasshopper in the oenocytes and very rarely in muscle tissue. By shaking these tissues in saline, the larvae could be easily removed. Infective larvae were observed in a minimum of 21 days after embryonated eggs had been fed to a grasshopper. Development took place equally well in both species of grasshoppers. Data on development of the larvae are given in Table 4.

Attempts to transmit the sparrow *Tetrameres* to young chicks proved negative in all of 11 trials. The age of the parasites in the grasshopper hosts varied from 45 to 60 days, and the period allowed for development in the chicks was from 30 to 75 days. The parasites in the grasshoppers were checked for larval stage and viability before they were fed to the chicks; thus it would appear that this parasite is probably not infective to young chicks.

SUMMARY

1. An apparently new species of *Tetrameres* has been found to parasitize English sparrows in Hawaii.
2. Adult male and female parasites were found invading the proventricular glands of sparrows throughout the year.
3. No more than one female per gland and from zero to four males with an average of 1.4 per gland were found in the proventriculus. This parasite, unlike other described *Tetrameres*, eventually protrudes from the outer stomach wall after invasion of a gland and growth within it.
4. The grasshoppers *Oxya chinensis* and *Conocephalus saltator* may serve as experimental intermediate hosts of the parasite, which reached the third larval stage in these hosts in a minimum of 21 days at room temperature.
5. Attempts to infect young chicks with third stage larvae of the sparrow *Tetrameres* failed in 11 trials.

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The Sponges of the Island of Hawaii[1]

M. W. de Laubenfels[2]

THE ISLAND OF HAWAII lies farthest to the east and south of the chain of islands which comprise the Hawaiian archipelago. It has an area of more than 10,000 square kilometers. From it, capes project slightly north of 20° and south of 19° north latitude, also slightly west of 156° and east of 155° west longitude. Its two highest volcanic peaks, Mauna Kea and Mauna Loa, project respectively 4,201 and 4,170 meters above sea level. The whole island consists of four amalgamated volcanic cones, rising from an ocean floor which is about 5 kilometers deep; thus the unit rises more than 9 kilometers above its substrate. Only comparatively narrow regions of shallow water bound the island. In fact, along the steep north shore, there is practically no area which has a depth of less than 10 or 20 meters. The other shores, however, do have offshore regions less than 10 meters deep, and up to as much as 100 meters wide. The northeast side receives the trade winds, and therefore heavy rainfall; as a result a small river empties into the sea at Hilo. No other permanent streams occur on the island.

In the summer of 1945, Professor R. W. Hiatt of the University of Hawaii made an intensive study of an extremely arid and inaccessible region on the south shore of Hawaii, known as Halapé. His collection of sponges was turned over to me for study.

In May, 1948, a grant from the University of Hawaii enabled me to make a rather thorough collection about the shores of the island. There I was given the utmost assistance by the officials of the Territorial Board of Agriculture and Forestry; on the east side by Mr. Ernest Yap; and on the west side by Mr. Homer Hayes. I am also grateful to the President of the Territorial Board of Agriculture and Forestry, Mr. Colin Lennox, and to the Director of the Division of Fish and Game, Mr. Vernon Brock, for their assistance in the project.

Studies were made by using small boats, both row boats and motor-powered craft. The sea bottom was carefully observed by means of a glass-bottom "viewing box." Assistance in collecting was rendered by "skin divers," who swim down to a depth of a few meters.

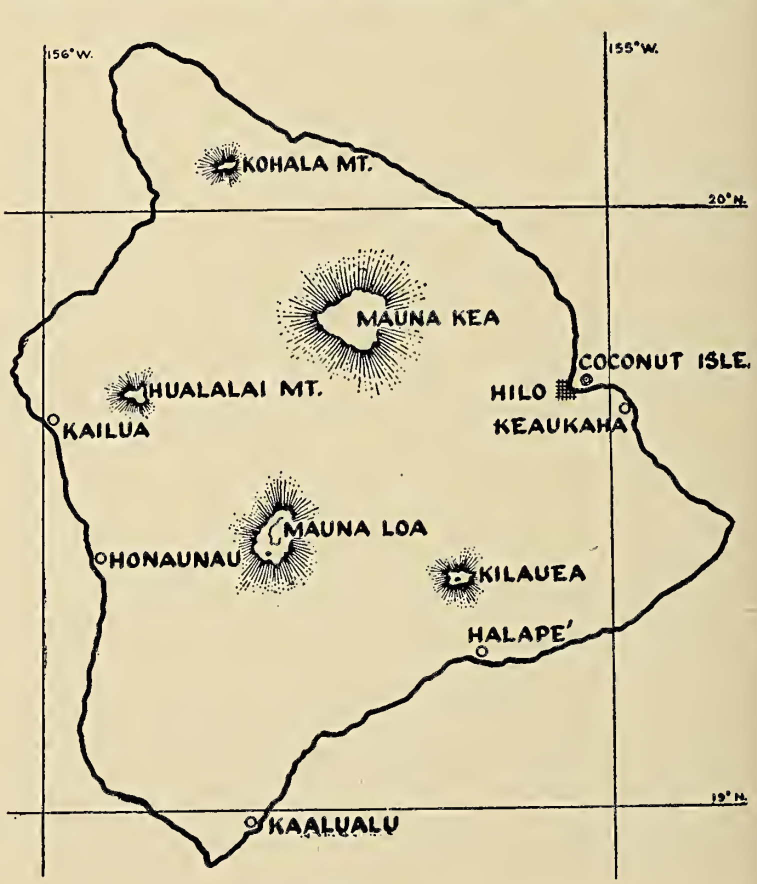

FIG. 1. The island of Hawaii, showing localities mentioned.

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[1] Contribution No. 7, Hawaii Marine Laboratory. Manuscript received June 27, 1950.

[2] Formerly Professor of Zoology, University of Hawaii; now Professor of Zoology, Oregon State College, Corvallis, Oregon.

Some collecting was possible by wading, especially by turning over stones. No dredging was used in the present study.

Because of the scarcity of suitable environment, the number of species of shallow-water sponges around the island of Hawaii is only moderate. Twenty-eight kinds are recorded, of which nine are here described as new. Four of the others are peculiar to the Hawaiian Islands and thus only about half of the species are represented elsewhere.

The sponges of Kaneohe Bay, island of Oahu, in the central portion of the Hawaiian Islands, have recently been described (de Laubenfels, 1950: 3–36). The species which are there described are not here redescribed, but the page reference is given. All others are described because of the possibility that later studies may lead to the conclusion that some are new species, although here identified with previously described names. Many early descriptions are seriously incomplete, so that identification with them must be tentative. A key to genera is also included, as follows:

KEY TO GENERA

1. No proper spicules present......... 2
Proper spicules present............. 3
2. Spongin network present........*Spongia*
Spongin network absent......*Chondrosia*
3. Spicules of silica present........... 4
Spicules of calcium carbonate present 27
4. Spicules only monaxon............ 5
Triaxons or tetraxons also present... 23
5. No microscleres present........... 6
Microscleres present................ 12
6. Spicules are tylostyles...........*Terpios*
Spicules are not tylostyles.......... 7
7. Spicules are of several sorts....*Rhaphisia*
Spicules are all simple oxeas........ 8
8. Extensive subdermal spaces present.. ....*Halichondria*
Extensive subdermal spaces absent... 9
9. Spicules conspicuously protrude from the surface...................*Phycopsis*
Spicules do not conspicuously protrude from the surface............. 10
10. Dermal network present, with meshes much finer than those of the interior ....*Callyspongia*
No such dermal network present.... 11
11. Sponge in the form of definite tubes ....*Reniera*
Sponge not tubular...........*Haliclona*
12. Microscleres are spirasters....*Spirastrella*
Microscleres not spirasters.......... 13
13. Microscleres include spherasters...*Tethya*
Microscleres do not include spherasters............................ 14
14. Microscleres only smooth microxeas ....*Petrosia*
Other microscleres present.......... 15
15. Microscleres only roughened raphides ....*Tedamia*
Other microscleres present.......... 16
16. Microscleres only toxas.......*Toxadocia*
Other microscleres present.......... 17
17. Microscleres only amphidiscs....... ....*Hiattrochota*
Other microscleres present.......... 18
18. Megascleres include acanthostyles... ....*Microciona*
Acanthostyles absent.............. 19
19. Megascleres only strongyles.*Xytopsiphum*
Other megascleres present.......... 20
20. Megascleres tylotes and oxeas.*Damiriana*
Megascleres monactinal............ 21
21. Microscleres do not include anisochelas.....................*Axocielita*
Microscleres do include anisochelas.. 22
22. Microscleres include toxas.......*Carmia*
Microscleres do not include toxas... ....*Mycale*
23. Sterrasters present..............*Geodia*
Sterrasters absent.................. 24
24. Aspidasters present..............*Erylus*
Aspidasters absent................. 25
25. Microscleres only euasters.....*Myriastra*
No astrose spicules present......... 26
26. Monoloph spicules present......*Plakina*
Monoloph spicules absent......*Plakortis*
27. Numerous oxeas present.......*Leuconia*
Oxeas rare or absent...........*Leucetta*

DESCRIPTIONS OF SPECIES

Spongia oceania de Laubenfels

Described in de Laubenfels (1950: 7).

This species appears to be common throughout the Hawaiian Islands. Hiatt found it at Halapé in 1945. I found it at Kaalualu and Honaunau, and, with the viewing box, observed numerous specimens (not collected), especially along the Kona coast from Honaunau to Kailua.

Haliclona permollis (Bowerbank) de Laubenfels

Fig. 2

This species is represented by U. S. National Museum, Register Number 22791 (Halapé No. I-106b), collected by Hiatt in August, 1945, at Halapé, on the undersides of rocks at the seaward edge of a rocky shore, depth less than 1 meter. I have found this species also on the island of Oahu.

This is a soft incrusting sponge, usually lavender in life. There is absolutely no dermal specialization of skeleton—the endosomal structures merely stop short. There are no extensive subdermal canals.

The skeleton comprises only one sort of spicule, an oxea 3 by 100 to 7 by 105μ. These are often arranged so as to outline polygonal meshes, each side just one spicule long. The spicules are joined to one another by spongin at the corners of these meshes. This structure is called isodictyal. In places there may also be tracts, almost fibers, of parallel rows of spicules held together by spongin.

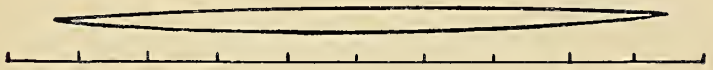

FIG. 2. *Haliclona permollis:* spicule, from a camera lucida drawing. (The scale shows 100 microns by tens.)

This species was first described as *Isodictya permollis* by Bowerbank (1866: 278) and transferred to *Haliclona* by de Laubenfels (1936: 40).

Reniera aquaeducta Schmidt

Fig. 3

This species is represented by U. S. National Museum, Register Number 22792 (My No. H. 79), collected May 15, 1948, at Keaukaha, at low tide, barely submerged. I found it again on May 16, 1948, at Kaalualu, and Hiatt took it in August, 1945, at Halapé.

This sponge consists of a number of tubes 20 to 25 mm. high, 3 to 9 mm. diameter, with walls 0.8 to 2 mm. thick. In life it was bluish violet and of spongy consistency. The surface is smooth.

The skeleton comprises only oxeas, 5 by 120 to 7 by 100μ. These are arranged much as in the preceding species.

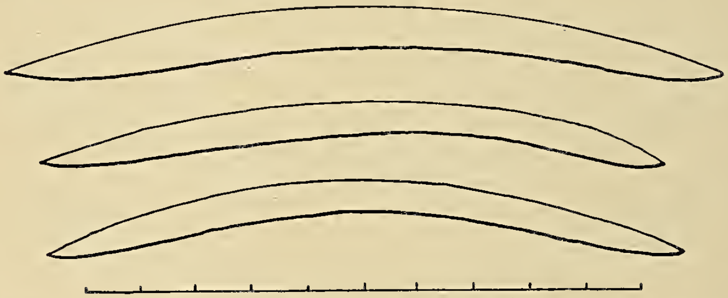

FIG. 3. *Reniera aquaeducta:* spicules, from camera lucida drawings. (The scale shows 100 microns by tens.)

This species was first described by Schmidt (1862: 72) from the Mediterranean as *Reniera aquaeductus*. It has since been recorded from various localities in both the North and South Atlantic, but this appears to be the first record for the Pacific Ocean. The species is probably cosmopolitan, but is nowhere abundant. An important discussion of it may be found in Burton (1930: 511).

Xytopsiphum meganese new species

Fig. 4

The type specimen of this species is U. S. National Museum, Register Number 22782 (My No. H. 83), collected May 16, 1948, at Kaalualu, at low tide, barely submerged.

This sponge is a paper-thin incrustation spreading laterally indefinitely. In life it was yellow-gray to ochre in color. There is a definite dermis with its contained spicules tangentially arranged.

The skeleton consists of strongyles, 3 by 210 to 3 by 240μ, and normally shaped arcuate chelas 16μ long.

The genus *Xytopsiphum* appears to be confined to the Hawaiian Islands; the type, *X. kaneohe* de Laubenfels, was described from Oahu by de Laubenfels (1950: 12). This Oahu species is characterized by slightly smaller megascleres (which is trivial) and by chelas radically different from those of the present species. The chelas of the former, while technically arcuate, are U-shaped with thick shafts and minute clads. The new species, *meganese*, is set off by having normal chelas with thin shafts and well-developed clads.

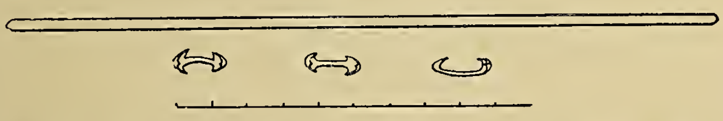

FIG. 4. *Xytopsiphum meganese:* spicules, from camera lucida drawings; one of the strongyles and three views of the arcuate chelas. (The scale shows 100 microns by tens.)

The name which is here selected is derived from the Greek words for "large" and "island," indicating that it is the species which is characteristic of the large island of Hawaii.

Callyspongia diffusa (Ridley) Burton

Described in de Laubenfels (1950: 12).

This species appears to be moderately common throughout the Hawaiian Islands. Hiatt found it at Halapé in 1945. I found it at Kaalualu in 1948.

Damiriana hawaiiana de Laubenfels

Described in de Laubenfels (1950: 14).

This species appears to be moderately common throughout the Hawaiian Islands. Hiatt found it at Halapé in 1945. I found it at Kailua in 1948.

Toxadocia violacea de Laubenfels

Described in de Laubenfels (1950: 14).

This species appears to be moderately common throughout the Hawaiian Islands. I found it not only on Oahu, but also near Hilo in 1948.

Petrosia puna new species

Fig. 5

The type specimen of this species is U. S. National Museum, Register Number 22780 (My No. H. 72; Halapé No. I-106), collected in August, 1945, by Hiatt at Halapé. It was said to be abundant on the undersides of stones at the seaward edge of a rocky shore at depths less than 1 meter.

This sponge is an incrustation, pale drab in life, of hard consistency. There is a tendency for its dermal spicules to be tangentially arranged. The endosome is densely packed with spicules and is only microcavernous. There is no localization of the different kinds of spicules.

The skeleton consists of megascleres of two size ranges. The larger type may be oxeas 13 by 166 μ, styles 14 by 132 μ, or strongyles 13 by 135 μ; each of the three occurs in approximately equal abundance. The size range of smaller spicules, almost as abundant as the larger, consists entirely of oxeas about 4 by 96 μ.

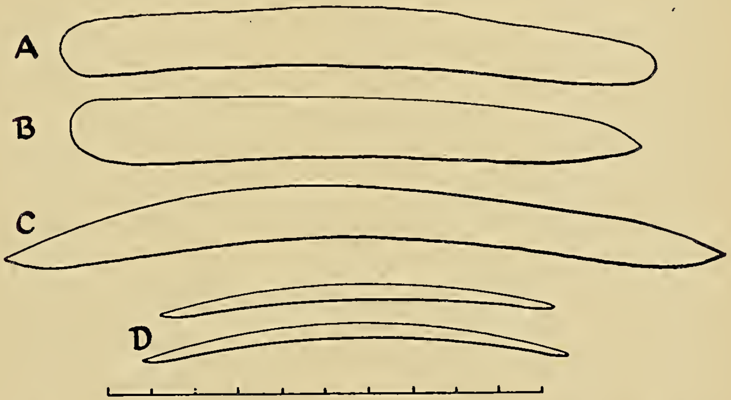

FIG. 5. *Petrosia puna:* spicules, from camera lucida drawings. A, Strongyle; B, style; C, oxea, larger size; D, two of the smaller oxeas. (The scale shows 100 microns by tens.)

This new species exhibits many points of difference from all others in the genus *Petrosia* except the genotype, which was first described as *Reniera dura* by Schmidt (1862: 77). This species, *dura*, is so far recorded only from the Mediterranean. From it the new

Hawaiian species differs as follows: The larger spicule category of *dura* is reported to comprise only oxeas and strongyles, whereas *puna* has, also, abundant styles. The smaller spicule category of *dura* comprises about equally abundant oxeas and strongyles; *puna* has only oxeas.

The specific name which is here selected is the Hawaiian name for the south coast of the island of Hawaii, the region where this species of *Petrosia* has been found.

Tedania ignis (Duchassaing and Michelotti) Verrill

Described in de Laubenfels (1950: 21).

This species appears to be quite common in the waters about the Hawaiian Islands. Hiatt found it at Halapé in 1945. I found it in 1948 near Hilo, also at Kaalualu, and near Honaunau.

Hiattrochota proteus de Laubenfels

Described in de Laubenfels (1950: 20).

This species is moderately common throughout the Hawaiian archipelago. In addition to the records on Oahu, I found it in 1948 at Kaalualu and at Honaunau.

Microciona maunaloa new species

Fig. 6

The type specimen of this species is U. S. National Museum, Register Number 22775 (My No. H. 74), collected May 14, 1948, near Hilo. This was obtained in Hilo Harbor near Coconut Island, at a depth of 2 meters, by diving.

This sponge is a paper-thin incrustation, spreading laterally indefinitely. In life it was a pale caramel-brown with definite pink tinges. In alcohol it turned blue. This reaction is unique and amazing. The consistency was soft.

In places where the whole sponge was only 400 μ thick there was an ectosomal region 150 μ thick. This was composed of a dermal membrane 10 μ thick, but otherwise almost no protoplasmic structures at all. Instead, it was full of tufts or bouquets of spicules, the heads at almost the same spot at the underlying surface of the endosome, the points all toward the outer surface but diverging at acute angles. The broad external expanse of each such bouquet is about 100 μ wide, the individual spicules about 150 μ long. The endosome is a rather dense mass of flesh, 250 μ thick, and, of course, permeated by canals and chambers. In it many spicules lie in confusion. Larger erect spicules pierce it, their heads on or near the substrate, their points toward the surface. The echinating spicules are confined to a thin region adjacent to the substrate.

The skeleton includes several size ranges of megascleres. The large spicules which protrude through the whole thickness of the incrustation are smooth tylostyles, upwards of 13 by 425 μ. Those scattered through the flesh are often about 9 by 240 μ. Those of the dermal tufts are about 6 by 160 μ, but some are only 6 by 120 μ. The echinating spicules are conspicuously spined acanthostyles about 8 by 42 μ. The microscleres include toxas 56 to 132 μ long and palmate isochelas 14 μ long; both types are quite commonplace in shape. In addition, however, there are abundant palmate isochelas of amazingly small size, only 5 to 6 μ long.

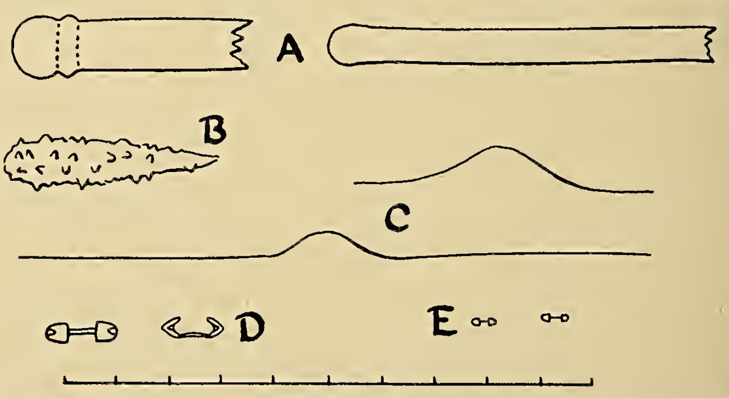

FIG. 6. *Microciona maunaloa:* spicules, from camera lucida drawings. A, Heads of tylostyles (the rest of these spicules is not shown); B, acanthostyle; C, two extremes of the toxa shape; D, larger palmate isochela; E, smaller isochelas. (The scale shows 100 microns by tens.)

This species is well characterized by its very small chelas. Several species in the genus

Eurypon have such microscleres, but not others in *Microciona*. The color is also unique; most species of *Microciona* are red. The extent to which the ectosomal spicules make symmetrical bouquets is also somewhat unusual in this very large genus.

The name which is here selected is that of the huge volcanic mountain Mauna Loa.

Mycale maunakea new species

Fig. 7

The type specimen of this species is U. S. National Museum, Register Number 22781 (My No. H. 75), collected May 14, 1948, in Hilo Harbor near Coconut Island at a depth of about 2 meters, by diving.

This sponge is incrusting, about 1 mm. thick. In life it was translucent, pale pink, and soft. It exhibited some recognizable oscules about 200 μ in diameter.

The ectosome is a transparent dermis, 50 to 75 μ thick, containing many microscleres but no megascleres. The endosome contains abundant spicular tracts which never anastomose and almost never branch. At the distal termination of each column, just under the dermis, the spicules of each tract diverge slightly, making dermal tufts which are much like miniature brooms. Such tufts are commonplace. These isolated non-reticulate tracts are 30 to 40 μ diameter and about 100 to 200 μ apart.

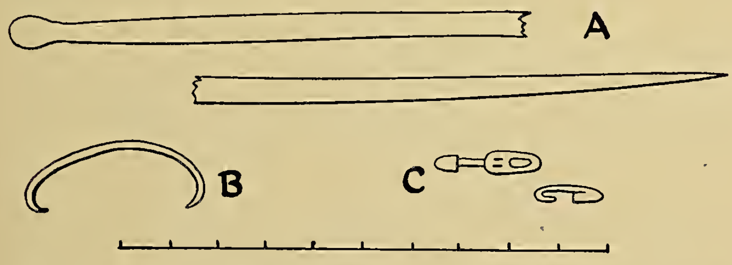

FIG. 7. *Mycale maunakea:* spicules, from camera lucida drawings. A, Tylostyle; B, sigma; C, palmate anisochelas. (The scale shows 100 microns by tens.)

The megascleres are smooth tylostyles 2 by 160 to 6 by 240 μ, often 5 by 210 μ. The microscleres include sigmas 37 to 42 μ in chord length and palmate anisochelas of peculiar shape. They are nearly isochelas, which is remarkable inasmuch as intermediates between isochelas and anisochelas are rare. They are very narrow with almost no lateral development on their convex side. Their lengths range from 13 to 22 μ.

Earlier (1950: 24) I identified a common sponge of Oahu as *Mycale cecilia*. It, too, is an incrusting sponge with narrow isochelas. But the microscleres in the Oahu sponge are quite commonplace in shape, and its tylostyles have unusually long heads, whereas the megascleres of the *Mycale* from the island of Hawaii are distinctive. At the moment it does not appear that any other species of *Mycale* has the utterly non-reticulate structure characteristic of the new species *maunakea*, and no other has chelas of the same peculiar shape. Those most nearly the same are found in *Mycale sulcata* Hentschel (1911: 307) (Australian and East Indian), but this species is digitate (not incrusting), has styles (not tylostyles), and has trichodragmas and two size ranges of chelas.

The name which is here selected is that of the extinct volcano Mauna Kea, which dominates the island of Hawaii.

Carmia contarenii (Martens) de Laubenfels

Fig. 8

This species is represented by U. S. National Museum, Register Number 22787 (My No. H. 84), collected May 16, 1948, at

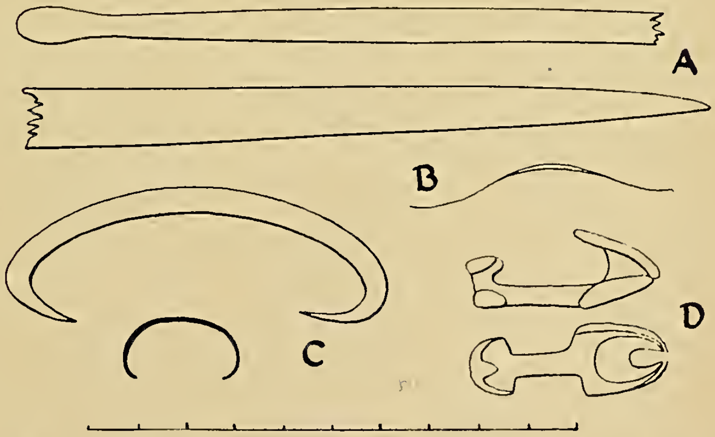

FIG. 8. *Carmia contarenii:* spicules, from camera lucida drawings. A, Tylostyle head and point, but the mid-portion is not shown; B, toxa; C, large and small sigmas; D, palmate anisochelas. (The scale shows 100 microns by tens.)

Kaalualu. It was found on the underside of a large stone barely submerged at low tide.

This sponge is incrusting, pale drab, and soft. The ectosome includes an optically evident reticulation of spicular tracts, as does the endosome. There are also many spicules which are merely strewn in confusion.

The megascleres are tylostyles with elongate heads, reaching a maximum of at least 13 by 350 μ, or 10 by 400 μ. The microscleres include sigmas 5 μ thick and 80 μ in chord length, smaller sigmas only 25 μ in chord length, toxas about 60 μ long, commonplace palmate anisochelas 40 μ long (which are often arranged in rosettes), and smaller palmate anisochelas only 10 μ long.

Martens in 1824 described *Spongia contarenii* from European waters. Topsent (1928: 78) redescribed it, placing it in *Mycale*. It was referred to *Carmia* by de Laubenfels (1936: 118). All records so far are from Europe, where it is common. The Hawaiian sponge which is here described is identified as *contarenii* only with grave doubts. It is so small a specimen and so devoid of striking characteristics, however, that it seems most unwise to erect a new species name for it. It exhibits no points of definite difference from *contarenii* and is at least closely related to the European species. Were more and better developed specimens available, grounds might be found for considering it a new species.

Axocielita kilauea new species

Fig. 9

The type specimen of this species is U. S. National Museum, Register Number 22779 (My No. H. 76), collected May 14, 1948, in Hilo Harbor near Coconut Island, at a depth of about 2 meters, by diving.

This sponge is incrusting and about 0.5 mm. thick. In life it was vermilion-red and of mediocre consistency. The surface is microhispid but lipostomous.

The ectosome does include a fleshy membrane, but it is rather vaguely developed. The whole sponge is so thin that it is also true that the endosomal structures lack conspicuous pattern.

The skeleton is composed of two types of megascleres. There are relatively large styles, often 12 by 280 μ, but sometimes at least 15 by 630 μ. Some are merely loose in the flesh, but others stand erect on the substrate, their points projecting slightly beyond the surface. The spicule heads that are in contact with the substrate are usually slightly spined. A second megasclere type is a smooth, straight tylostyle, about 2 by 144 μ in dimensions. These are often strewn in confusion but are more common at or near the surface than they are near the base of the sponge. The microscleres include commonplace toxas, 30 to 60 μ long, usually 50 μ. There are also peculiar chelas, perhaps of two sorts. Chelas of this type (or these types) are each about 14 μ long. Practically all of them reveal merely a C shape, but after long search one face-view of a palmate isochela of apparently commonplace form was found. When such chelas lie on their sides, they look somewhat like the above-mentioned C shape, but they are very likely to lie in such a position as to reveal the shape of their shovels; here they do not. Two explanations may exist to explain the peculiar situation in *Axocielita kilauea*. First, there may be such wide, peculiar lateral expansions on the shaft that equilibrium results from the side position. Second (and more likely), it may be that nearly all of these chelas have such exceedingly narrow shovels that they inevitably fall over on their sides.

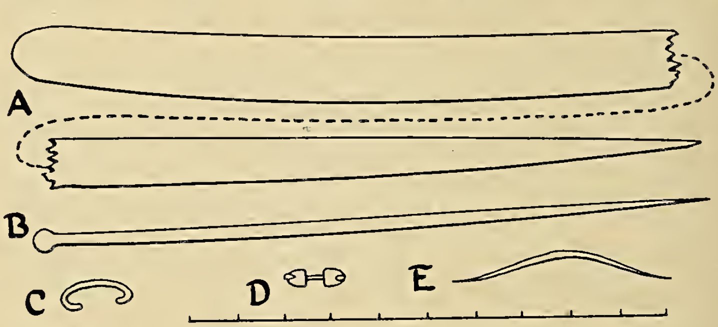

FIG. 9. *Axocielita kilauea:* spicules, from camera lucida drawings. A, Style; B, tylostyle; C, peculiar microsclere, probably in isochela, common in this species; D, the one typical palmate isochela; E, toxa. (The scale shows 100 microns by tens.)

The other species now in *Axocielita* have rather large, commonplace palmate isochelas. The species *kilauea* also exhibits minor differences in the sizes and shapes of its megascleres.

The specific name selected is that of the famous volcanic crater in the southern portion of the island of Hawaii.

Phycopsis aculeata (Wilson) de Laubenfels

Fig. 10

This species is represented by U. S. National Museum, Register Number 22784 (My No. H. 85), collected May 16, 1948, while wading, from a substrate of volcanic rock barely below low tide at Kaalualu.

This sponge is massive, the fragment collected being about 1 by 2 by 3 cm. The surface is strongly hispid and lipostomous. In life it was dark gray with an interior much paler than the exterior. The consistency was stiff and the sponge rather easily broken.

The ectosome, as delimited by darker color and somewhat denser structure, is about 2 mm. thick. The endosome is microcavernous, also dense.

The skeleton is composed of but a single sort of spicule. This is a smooth, sharply pointed oxea, 23 by 940 to 32 by 1,200 μ or more. The few megascleres that are smaller are doubtless developmental forms. These spicules are sometimes in confusion, but a significantly large proportion of them stand perpendicular to the surface, with about a third of their length protruding from it.

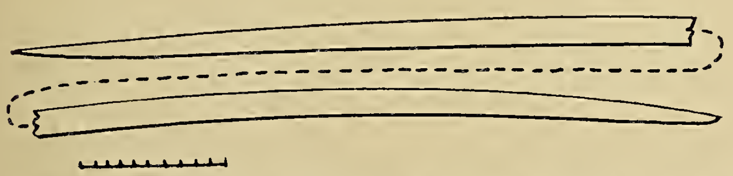

FIG. 10. *Phycopsis aculeata:* spicule, from a camera lucida drawing. (The scale shows 100 microns by tens.)

This species was first described as *Axinyssa aculeata* by Wilson (1925: 445), from the Philippines, and was transferred to *Phycopsis* by de Laubenfels (1936: 131).

Halichondria dura Lindgren

Fig. 11

This species is represented by U. S. National Museum, Register Number 22785 (My No. H. 73), collected May 14, 1948, from a depth of 2 meters in the harbor of Hilo, by diving.

This sponge is incrusting and reaches a thickness of about 3 mm. In life it was yellow and of a hard consistency. The surface is somewhat hispid and is lipostomous.

The ectosome is definitely set off as a layer perhaps 60 μ thick by the occurrence of extensive subdermal cavities which are 200 μ wide and 200 μ high. The endosome is of "crumb-of-bread" structure with abundant spicules in confused arrangement.

The skeleton consists chiefly of just one kind of spicule, an oxea. There is great variation in size. Very many of these spicules, however, are between 20 by 650 and 27 by 680 μ.

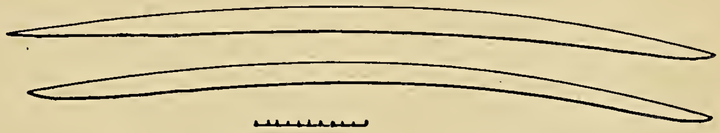

FIG. 11. *Halichondria dura:* spicules, from camera lucida drawings. (The scale shows 100 microns by tens.)

The identification of this specimen is made with some hesitation. The hispid surface is not typical of *Halichondria*, but some portions of *Halichondria* are slightly hispid, and the present specimen is only slightly hispid. The other items are all quite typical of *Halichondria*. Within this huge genus, the closest to the Hilo sponge is *dura*. This was described by Lindgren (1897: 480) from Java.

Rhaphisia myxa new species

Fig. 12

The type specimen of this species is U. S. National Museum, Register Number 22783 (My No. H. 82), collected May 16, 1948, at Kaalualu, by wading. It was just below low tide on a substrate of volcanic rock.

This sponge is incrusting and 1 to 2 mm.

thick. In life it was white; the consistency was extremely slimy but, at the same time, sticky or glue-like. The surface is smooth and lipostomous.

The ectosome is not sharply set off from the endosome. The latter is microcavernous with some vague tracts, about 100 to 125 μ apart and 20 μ in diameter, and containing 3 to 10 spicules per transverse section.

The skeleton, other than the ubiquitous colloidal stuff, consists of spicules which may be regarded as comprising only a single category but with much individual variation. Some are simple, smooth, sharply pointed oxeas 4 by 112 μ. Others, probably juvenile, are as small as 1 by 85 μ. Many are as large as from 5 by 117 to 6 by 150 μ, and the larger ones frequently have unusual shapes. It is common for them to be centrotylote, and some are also strongylote. Many, not centrotylote, have two distinct angular bends near the mid-point.

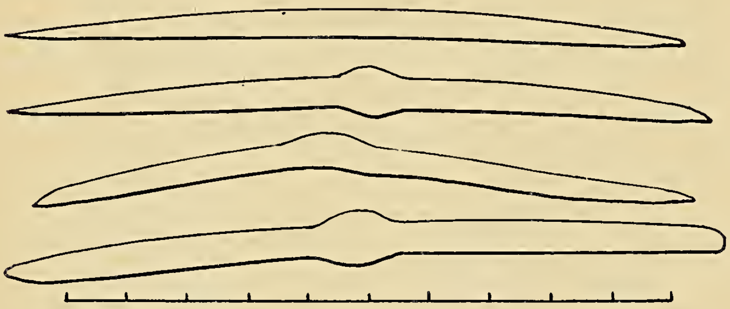

FIG. 12. *Rhaphisia myxa:* spicules, from camera lucida drawings. (The scale shows 100 microns by tens.)

All the sponges now in *Rhaphisia*, except the genotype, have much larger spicules than those of this new species. The genotype is *Rhaphisia laxa* Topsent (1892: xvii) from the Mediterranean region and is clearly the closest relative to the Hawaiian form. It also was viscous, but lacked the peculiar spicule shapes of *myxa*.

The species name here selected is derived from the Greek for slimy, and refers to the extreme development of a viscous colloid by this species.

Spirastrella keaukaha new species

Fig. 13

The type specimen of this species is U. S. National Museum, Register Number 22777 (My No. H. 78), collected at Keaukaha, May 15, 1948, far back from the surf on volcanic rock barely below low tide. This species was found also at Kaalualu and at Honaunau and is abundant all around Hawaii.

This is an incrusting species often as much as 3 mm. thick, spreading laterally indefinitely. In life it was orange-brown to red-brown, with a paler interior, but often with a very dark layer about 0.6 to 1 mm. below the surface—a layer about 50 to 120 μ thick. The consistency was rather like that of cheese. The surface is smooth and lipostomous, but subdermal canals (which doubtless terminated at oscules which close quickly and readily) are easily visible.

The ectosome is characterized by greater density and pigmentation than the microcavernous endosome. The microscleres are exceedingly abundant in the dermal layer.

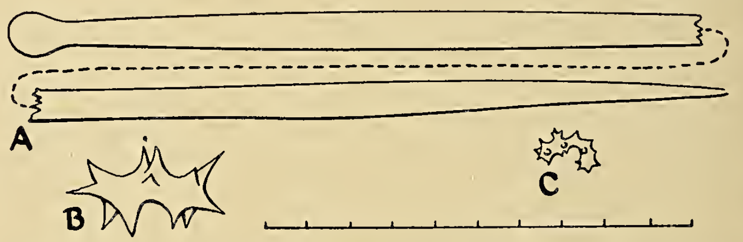

FIG. 13. *Spirastrella keaukaha:* spicules, from camera lucida drawings. A, Tylostyle; B, larger spiraster; C, smaller spiraster. (The scale shows 100 microns by tens.)

The skeleton is composed of tylostyles and spirasters. The former are smooth and straight, 8 by 328 μ, usually in confusion but oftenest with points directed toward the surface of the sponge. The microscleres are of two size ranges. The larger spirasters are about 40 μ long, the smaller about 16 μ long. Both kinds are astonishingly nearly straight, only slightly spiral. The smaller variety has spines which are more obtuse than might be expected.

There are now many names in the genus *Spirastrella*, and the opinion is here expressed that all the massive or ramose forms need to be removed to other genera, such as *Anthosigmella*. The remainder, all incrusting forms, are all much alike and require separation on slender margins of difference. It is here considered probable that there really are about six species in the world. This new species, *keaukaha*, is distinctive for the dark subdermal layer (not quite always present) and the almost straight axis of the spirasters.

The species name selected is that of the locality of the type specimen.

Terpios zeteki de Laubenfels

Described in de Laubenfels (1950: 28).

This species appears to be very common throughout the Hawaiian Islands. I found it to be abundant, not only on Oahu, but also at Kaalualu and at Honaunau in 1948.

Tethya diploderma Schmidt

Described in de Laubenfels (1950: 30).

This species appears to be abundant throughout the Hawaiian Islands. I found it to be so on Oahu and also found specimens at Kaalualu and Honaunau in 1948. Hiatt found it at Halapé in 1945.

Myriastra debilis Thiele

Fig. 14

This species is represented by U. S. National Museum, Register Number 22789 (My No. H. 71), collected in August, 1945, by R. W. Hiatt at Halapé. It was growing on dead coral in the surf area.

This species is massive, reaching a thickness of at least 1 cm. In life it was pale and the consistency was cartilaginous. The surface is partly smooth and partly hispid, and the Hawaiian specimens appear lipostomous.

The ectosome is vaguely corticate, the endosome is semi-radiate. Presumably all well-developed specimens will be definitely corticate and of radiate architecture with the spicules all more or less perpendicular to a spherical surface.

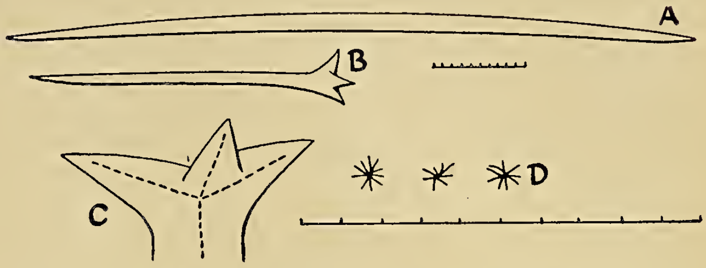

FIG. 14. *Myriastra debilis:* spicules, from camera lucida drawings. A, Oxea; B, plagiotriaene; C, head or cladome of a plagiotriaene; D, three oxyeuasters. (The smaller scale matches A and B, showing 100 microns by tens. The larger scale matches the more highly magnified C and D, showing 100 microns by tens.)

The skeleton consists of very numerous spicules, often in confusion, but many are perpendicular to the surface. There are smooth, sharply pointed oxeas 18 by 720 μ. There are plagiotriaenes with rhabds 16 by 320 μ and very short clads; the latter are often less than 32 μ long. Some broken bits of long thin spicules, only 2 or 3 μ in diameter, are here interpreted as being fragments of the rhabds of anatriaenes whose cladomes (not found) formerly protruded from the surface but have been broken off. The microscleres are oxyeuasters about 10 μ in diameter. They are astonishingly rare.

Thiele (1900: 25) described *Myriastra debilis* from the East Indies. He did find the anatriaenes, but their absence from the Hawaiian specimen does not necessarily mean that it is not the same species. Thiele's specimens agreed with ours in lacking the protriaenes and in having similar short-clad plagiotriaenes and microscleres.

Geodia gibberella new species

Fig. 15

The type specimen of this species is U. S. National Museum, Register Number 22778 (My No. H. 66), collected in August, 1945, by R. W. Hiatt at Halapé. It was found at a depth of 3 meters on a coral "head" in the channel between the steep shore and a small off-shore island. This species seems to be uncommon in the Hawaiian Islands.

This sponge is massive to subglobular and is over 1 cm. in diameter. Its color is dirty gray. The surface consistency is hard, almost stony (due to the sterraster armor), but somewhat flexible. The interior is softer and more compressible. The surface is smooth and lipostomous.

The ectosome is a fibrous cortex nearly 1 mm. thick and is densely packed with sterrasters. The endosome shows a fundamental tendency to radiate architecture but realizes this structure only vaguely.

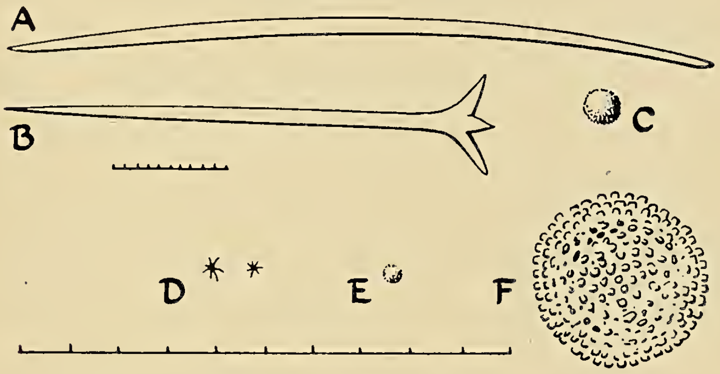

FIG. 15. *Geodia gibberella:* spicules, from camera lucida drawings. A, Oxea; B, plagiotriaene; C, sterrasters; D, oxyeuasters; E, spheraster; F, sterraster. (The smaller scale for A, B, and C shows 100 microns by tens. The larger scale matches the more highly magnified D, E, and F and shows 100 microns by tens.)

The megascleres are sharp-pointed oxeas 15 by 620 μ and plagiotriaenes with rhabds 18 by 410 μ and clads 60 μ long. The microscleres include the large sterrasters which are characteristic of *Geodia*, but not as large as they are in most of the species of this genus; they have a diameter of only about 37 μ and are nearly spherical. The mature sterrasters are practically all in the cortex, but their sharp-rayed juvenile forms, as usual, occur sparingly in the endosome. Additional microscleres of two sorts also occur—oxyeuasters 6 μ in diameter and oxyspherasters only 5 μ in diameter. The euasters are abundantly present in a thin layer over the outer surface of the sterraster armor.

Lamarck (1815: 333) described *Geodia gibberosa*, the type of the genus. It is an abundant West Indian species, not certainly recorded from any other locality. It and this Hawaiian species stand out from the rest of the genus for lack of anatriaenes and protriaenes and for the possession of minute spherasters. Clearly *gibberosa* is the nearest relative to *gibberella*. But the West Indian *Geodia* has large (30 μ) oxyeuasters.

The species name which is here selected is a diminutive of *gibberosa*.

Erylus proximus Dendy
Fig. 16

This species is represented by U. S. National Museum, Register Number 22786 (My No. H. 57), collected February 19, 1948, by dredging at a depth of 50 meters in the open ocean 2.5 kilometers south of Pearl Harbor, Oahu. This species is not common, but is widely distributed in the Hawaiian archipelago. Hiatt collected it (his No. I-38a G) in August, 1945, at Halapé.

This is an amorphous sponge, often growing in interstices of dead coral or cracks in rocks. In life the ectosome was dark gray to black, the endosome a paler gray or drab. The consistency was cartilaginous. The surface is microtuberculate. The pores are about 70 μ in diameter and 300 to 400 μ apart. The rare oscules are about 1.5 mm. in diameter.

The ectosome is a fibrous cortex densely

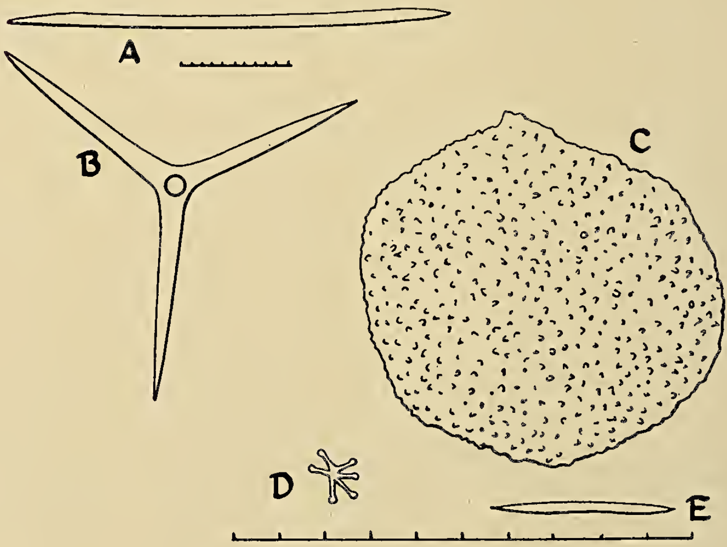

FIG. 16. *Erylus proximus:* spicules, from camera lucida drawings. A, Oxea; B, tetraxon; C, aspidaster; D, tylaster; E, microxea. (The smaller scale for A and B shows 100 microns by tens. The larger scale matches the more highly magnified C, D, and E and shows 100 microns by tens.)

packed with aspidasters and is about 100 μ thick. The endosome is microcavernous and confused.

The skeleton includes oxeas 8 by 500 to 12 by 420 μ and tetraxons that might almost or quite suitably be called calthrops. Their nearly equal rays are 5 by 105 to 15 by 200 μ; one is often slightly longer than the others and might be considered a rhabd but is not clearly so. In addition to these definite megascleres, there are oxeas 3 by 50 μ, perhaps also megascleres, but probably to be regarded as microscleres. There are abundant aspidasters in the cortex. These microscleres are less than 10 μ thick, but are 80 μ in diameter—irregularly rounded discs. They are densely covered with conical projections, probably homologous with the rays of asters, but also resembling the spines on acanthoscleres. Finally, eutylasters 15 μ in diameter are also present.

This species was described by Dendy (1916: 258) from the Indian Ocean, the only previous record. The agreement with Hawaiian specimens is amazingly close.

Plakortis simplex *Schulze*

Described in de Laubenfels (1950: 33).

This species appears to be moderately common throughout the Hawaiian Islands. I found it at Keaukaha in 1948.

Plakina monolopha Schulze

Fig. 17

This species is represented by U. S. National Museum, Register Number 22788 (My No. H. 87), collected May 17, 1948, at Honaunau at a depth of about 1 meter.

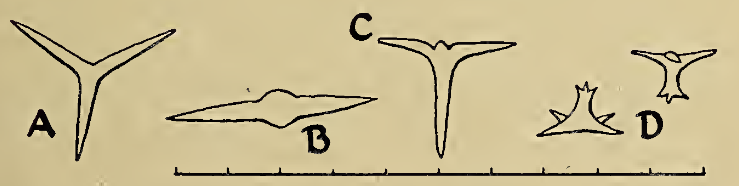

FIG. 17. *Plakina monolopha:* spicules, from camera lucida drawings. A, Triaxon; B, centrotylote oxea; C, tetraxon; D, monoloph spicules. (The scale shows 100 microns by tens.)

This is a thin crust 0.6 to 0.8 mm. thick, drab, soft, and lipostomous. There is little ectosomal specialization. The endosome is densely fleshy, with canals 100 μ in diameter perpendicular to the surface and 200 to 500 μ apart. Doubtless in life these ascended to minute oscules.

The commonest spicules are regular triaxons, with rays 3 by 20 to 4 by 24 μ. There are sagittal tetraxons with two clads about this same size, the third clad very small, and the rhabd slightly longer. There are oxeas, about 4 by 36 μ, usually centrotylote. Finally, there are the distinctive monoloph calthrops; these tetractinellid or pentactinellid spicules have three or four simple sharp smooth rays, about 3 by 12 μ, in one plane, as divergent from each other as possible. The odd ray is at right angles to them and about as long but terminates in about four sharp spines.

This species was first described by Schulze (1880: 407) from the Mediterranean. It has since been recorded from various European regions and by Thiele (1898: 28) from Japan. It is doubtless cosmopolitan, but neither really abundant anywhere nor ever conspicuous.

Chondrosia chucalla de Laubenfels

This species is represented by U. S. National Museum, Register Number 22790 (My No. H. 77). It was collected at Halapé in 1945 by R. W. Hiatt (His No. II 679). This was from lava rock in a tide pool at the west end of Keaoi Island, at low tide. It was common in this vicinity.

This is a massive, subspherical sponge. The Hawaiian specimens are about 1 cm. thick and 3 by 6 cm. in lateral dimensions. The color is black as to surface, dark drab as to interior. The surface is smooth, shining, and slimy. The pores are all closed, but oscules, each about 1 mm. in diameter, can be discovered in groups of 2 or 3, such groups about 1 cm. apart.

The skeleton of all sponges probably includes a greater or lesser amount of non-living colloidal material. In this species (and genus) there is a relatively large quantity of this, and here it is in a fairly stiff gel condition. The ordinary methods of search reveal no inorganic skeleton—that is to say, no spicules at all. Exceedingly rare spicules may be present, but this is surmise.

This species was first described as *Chondrosia collectrix* by Lendenfeld (1888: 74) from Australia, its only previous locality record. There was already a different *Chondrosia collectrix*, that of Schmidt (1870: 25). Therefore de Laubenfels (1936: 184) set up the new name *chucalla* for Lendenfeld's species.

Leuconia kaiana new species

Fig. 18

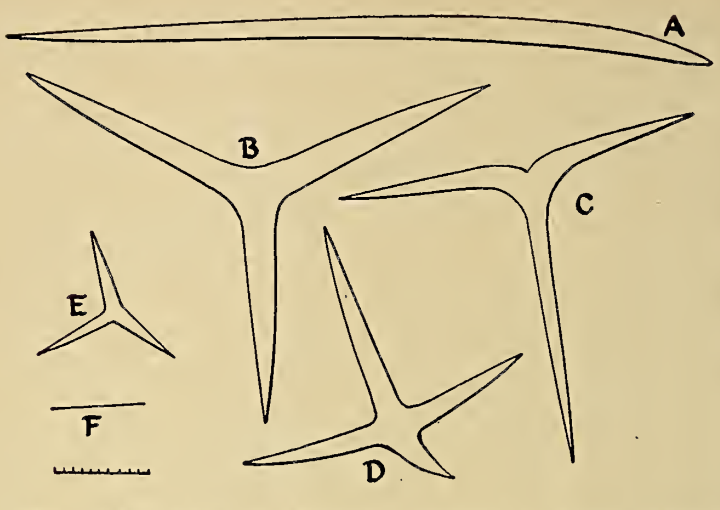

FIG. 18. *Leuconia kaiana:* spicules, from camera lucida drawings. A, Oxea; B, regular triaxon of the chamber layer; C, sagittal triaxon, from subdermal area, and oscular region; D, tetraxon from lining of cloaca—the curved ray projects into the cloaca; E, smaller triaxon; F, microxea. (The scale shows 100 microns by tens.)

The type specimen of this species is U. S. National Museum, Register Number 22776 (My No. H. 86). This was collected in August, 1945, by R. W. Hiatt (His No. III 870) at Halapé. This species was found abundantly on coral about 2 meters deep on the outer, surf-pounded slope of the small island of Keaoi. This, or a similar *Leuconia*, is widespread in the Hawaiian region. I have found it also at Pearl Harbor, Oahu.

This species is hollow—that is to say, it possesses a relatively large cloaca. The shape is very roughly cylindrical, larger in the middle than at the ends, but the cylindrical shape is further modified by the occurrence of small, short branches. A total height of at least 3 cm. is reached and a diameter of 8 mm.; the walls are almost 1 to 2 mm. thick. The cloaca penetrates nearly the entire length of the sponge.

The color is whitish and the consistency fragile. The surface is hispid, but there is no coronal fringe around the oscules. The latter are about 2 mm. in diameter.

The ectosome contains many tangent rays of polyactinal spicules. The endosome has an architecture perhaps to be termed rhagon, but almost that which has been termed sylleibid. In the latter, the flagellate chambers are concentrated in clusters, but the clusters are rather distinct from each other.

The skeleton includes oxeas 25 by 750 μ, perpendicular to the surface, and partially protruding so that they render it hispid. The spicules of the chamber layer are chiefly regular triaxons with rays about 35 by 300 μ. Many sagittal triaxons with their clads near the surface and parallel to it also occur. The clads are about 20 by 200 μ; the rhabds penetrate the chamber layer perpendicular to the surface and are about 20 by 300 μ. Many tetraxons line the cloaca, two medium-sized rays tangentially placed in its lining, a small bent ray protruding into the cloaca, and a longer ray piercing the chamber layer, perpendicular to the cloacal surface. The latter ray is about 25 by 225 μ; the paired rays are about 25 by 175 μ in dimensions. Many small, regular triaxons are present, especially near the inner and outer surfaces. Their rays are about 10 by 100 μ. Microxeas also occur, only 1 by 90 μ.

The species is probably closest to that *Leuconia* which was first described as *Leucandra taylori* by Lambe (1900: 261) from Vancouver Island, British Columbia. The smaller triaxons of Lambe's species had rounded (strongylote) ends, and it did have a coronal fringe around the oscules. Both *taylori* and *kaiana* seem related to the common species of the genus *Rhabdodermella* of the American Pacific coast.

The species name which is here selected is that of the famous ancient Hawaiian nobleman, Prince Kaiana.

Leucetta solida (Schmidt) Dendy and Row

Described in de Laubenfels (1950: 34).

This species appears to be moderately common about the Hawaiian Islands. I found it on Oahu, and R. W. Hiatt found it at Halapé in August, 1945.

ECOLOGICAL OBSERVATIONS

My first study was made in Hilo Harbor, near Coconut Island. The representative of the Territorial Board of Agriculture and Forestry who accompanied me was a capable diver and brought up much material for examination from depths of about 2 meters. The location, although on the windward side of the island, is sheltered from the full force of the sea. No sponges were common in this area, nor were any found to be large. On the other hand, the fauna here was unique. Five species were found—three were new, one (*Halichondria*) perhaps new although tentatively identified, and another has been reported from only one other locality (Oahu, also in the Hawaiian Islands). The species are:

Halichondria dura (?): also East Indies (?).
Toxadocia violacea: also Oahu.
Mycale maunakea: new.
Axocielita kilauea: new.
Microciona maunaloa: new.

My second study was made at Keaukaha, near Hilo on the windward coast but a location which was much more exposed to the force of the ocean than was the one at Hilo. Only a few years previously (1946) this coast had been devastated by a huge tsunami (a so-called "tidal wave"). Here the collecting was done by wading at low tide. Four species of sponge were found: three are certainly world-wide and the fourth (*Spirastrella*) is possibly also world-wide although here it is tentatively identified as a new species. These species are:

Tedania ignis: also Oahu, Kaalualu, Halapé, West Indies, etc.
Reniera aquaeducta: also Halapé; circumequatorial.
Plakortis simplex: also Oahu; circumequatorial.
Spirastrella keaukaha: new (?); also Kaalualu and Honaunau. Closely related species are equatorial.

My third study was made at Kaalualu, near the extreme southern point of the Hawaiian Islands. Here again we collected by wading at low tide. I found the greatest variety of sponges here of any place studied on the island of Hawaii—10 species in all. They are:

Callyspongia diffusa: also Oahu, Indian Ocean, East Indies.
Xytopsiphum meganese: new.
Tedania ignis: also Keaukaha, Halapé, Oahu, West Indies, etc.
Carmia contarenii: also European, etc.
Hiattrochota proteus: also Oahu and Honaunau.
Phycopsis aculeata: also Philippines.
Rhaphisia myxa: new.
Spirastrella keaukaha: also Keaukaha and Honaunau.
Terpios zeteki: also Oahu, Halapé, Honaunau, and Panama.
Tethya diploderma: also Oahu, Halapé, Honaunau, and circumequatorial.

My fourth study was made at Honaunau, on the sheltered lee coast (Kona Coast) on the west side of the island. Here collections were made with the help of representatives of the Territorial Board of Agriculture and Forestry, who dove down to depths of 2 meters to collect specimens.

After collections at Honaunau, studies were made along the Kona Coast as far north as Kailua, but by so doing we were able to locate just one additional species (*Damiriana hawaiiana*).

It should be observed that, of any of the places studied on the larger island, the sponge fauna of the Kona Coast of Hawaii is the most like that of the island of Oahu. Seven species were found, of which five have already been reported from Oahu, and I strongly suspect that the two additional species also occur on Oahu. The species are:

Spongia oceania: also Oahu and Halapé.
Hiattrochota proteus: also Oahu and Kaalualu.
Damiriana hawaiiana: also Oahu.
Spirastrella keaukaha: also Keaukaha and Kaalualu.
Tethya diploderma: also Oahu, Kaalualu, Halapé; circumequatorial.
Terpios zeteki: also Oahu, Kaalualu, and Panama.
Plakina monolopha: also Mediterranean, Japan, etc.

As already noted, R. W. Hiatt made a most interesting ecological study in August, 1945, at Halapé. This is somewhat farther north and east than Kaalualu. The study was made along a stretch of coast so nearly inaccessible that it was probably in a natural state and not disturbed by human meddling. The region may be analyzed into three subdivisions as follows:

1. The shore of the large island. There were steep cliffs of lava, boulders at the water's edge, one small patch of sand, and some tide pools.
2. A shallow, protected area inside the lee of a small island. The depth was about 4 meters, with scattered coral heads. A current of about 2 to 3 kilometers per hour set through this area, running parallel to the coast.
3. A small island called Keaoi—a sort of pahoehoe blister with some tide pools. The outer edge of this island was pounded by surf.

Sponges were recorded as follows:

1. Under rocks, just below tidemark
    Halichondria permollis: world-wide.
    Reniera aquaeducta: world-wide.
    Petrosia puna: new, rare.
    Tethya diploderma: world-wide, common.
    Geodia gibberella: new, uncommon.
2. Collected by diving
    Spongia oceania: local, common.
    Tedania ignis: wide distribution, common.
    Tethya diploderma: world-wide, common.
    Geodia gibberella: local, not common.
3. In various locations on Keaoi islet
    Spongia oceania: local. This was found on a shelf in a cove, also deep on the exposed outer edge.
    Damiriana hawaiiana: local, rare.
    Tedania ignis: wide distribution, abundant in a variety of locations.
    Myriastra debilis: also East Indies. This occurred where it received the full force of the surf. On the mainland I have found species of *Myriastra* similarly placed.
    Chondrosia chucalla: also Australian. This was common in some tide pools on the islet.
    Leuconia kaiana: new. This was common, in deep water on the exposed outer edge.
    Leucetta solida: world-wide. This genus often occurs in these exposed situations.

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The Scientific Name of the Nehu, an Engraulid Baitfish of the Hawaiian Islands[1]

WILLIAM A. GOSLINE[2]

The nehu, a small baitfish commonly used for tuna fishing in Hawaiian waters, was originally described as *Stolephorus purpureus* in 1900 by Fowler (1900, *Acad. Nat. Sci. Phila., Proc.*, p. 497). Since that time it has been variously assigned to the genera *Stolephorus*, *Anchovia*, *Anchoviella*, *Engraulis*, and *Scutengraulis*, and no agreement has been reached. Though future revision of the anchovies on a world-wide basis may show that the nehu belongs elsewhere, under the present classification of the group it may best be allocated to the genus in which it was placed originally as *Stolephorus purpureus*.

Of the five genera to which the nehu has been assigned, *Stolephorus*, *Anchoviella*, and *Engraulis* deserve most serious consideration. Jordan and Seale in their now outdated "Review of the Engraulidae" (1926, *Mus. Comp. Zool., Bul.* 67: 403) place the nehu in the genus *Anchoviella.* Hardenberg (1933, *Natuurk. Tijdschr. Neder.-Indie* 93: 242) believes that the three genera *Engraulis*, *Anchoviella*, and *Stolephorus* as defined by Jordan and Seale cannot be maintained and should be combined under the oldest generic name, *Stolephorus*. Hildebrand (1943, *Bingham Ocean. Coll., Bul.* 8(2): 108) resurrects the generic name *Anchoviella* for some American anchovies, but on a different basis from *Anchoviella* of Jordan and Seale. Hildebrand fails to state how his *Anchoviella* differs from *Stolephorus*, and a comparison between the American *Anchoviella* as defined by Hildebrand and the Indo-West-Pacific *Stolephorus* remains to be made. Nevertheless, since *Stolephorus* is the older of the two generic names and since the Hawaiian Islands have a basically Indo-West Pacific fauna, it seems safe to conclude that the nehu belongs with *Stolephorus* rather than with *Anchoviella.*

Both Hildebrand (*op. cit.*) and Blackburn (1950, *Austral. Jour. Mar. Freshwater Res.* 1(1): 5) likewise resurrect *Engraulis* from Hardenberg's synonymy of *Stolephorus.* The nehu does not belong in *Engraulis* as defined by these authors and thus, by elimination, remains with *Stolephorus.*

Two other problems of nehu nomenclature, though long since solved, continue to haunt ichthyological literature. One is the application of the name *Stolephorus* itself. Lacépède, who proposed the name, included under it species of two different families and designated no genotype. The question therefore arose as to which genus of which family the name *Stolephorus* should be applied. This matter was eventually resolved by the International Commission on Zoological Nomenclature, which (Opinion 93) designated *Stolephorus commersonianus*, a fish of the nehu group, as genotype of *Stolephorus.* Unfortunately, Fowler, Whitley, and Blackburn continue to apply the name *Stolephorus* erroneously to a genus of herring-like fishes.

Finally, *Anchoviella mauii* was described by Fowler and Bean (1924, *U. S. Natl. Mus., Proc.* 63(19): 4) as new and as from Maui. However, Fowler has since pointed out (1934, *Bernice P. Bishop Mus., Mem.* 11(6): 387) that the species is not new and that the Maui record is not correct. The nehu, *Stolephorus purpureus*, thus remains the only anchovy recorded from the Hawaiian Islands.

I am particularly indebted to Prof. C. L. Hubbs of the Scripps Institution of Oceanography and Prof. G. S. Myers of Stanford University for their advice on this matter.

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[1] Contribution No. 5, Hawaii Marine Laboratory.

[2] Department of Zoology, University of Hawaii. Manuscript received November 29, 1950.

Records and Descriptions of Some Micronesian Psyllidae (Homoptera)[1]

LEONARD D. TUTHILL[2]

DR. TEISO ESAKI of Kyushu University, Fukuoka, Japan, has very kindly placed at my disposal the collections of Psyllidae made during his expeditions to the islands of Micronesia during the years 1936 to 1940. Only a few collections have been made in this area and undoubtedly many more members of this family remain to be discovered there. A few species which are widespread throughout the Pacific are represented in the material included. The remainder appear to be unnamed and probably represent forms endemic to the island or group from which they were taken. All specimens bear the collector's label of Teiso Esaki except where otherwise indicated.

The figures have been prepared by Evan L. Gillespie of the Department of Zoology and Entomology, University of Hawaii.

Mesohomotoma hibisci (Froggatt)

Marianna Islands: Charanka, Saipan, October 31, 1937.

Caroline Islands: Paliker-Kolonia, Ponape, December 30, 1937, January 16, 1938, and July 16, 1939; Nipit-Kapiroi-Reitao, Ponape, July 21, 1939; Lelo, Kusaie, November 30, 1937.

This species is common on the young foliage of *Hibiscus tiliaceus* L. throughout most of the Pacific islands. Esaki notes that it is gregarious and that *Arbela hibisci* Esaki and Ishihara, a nabid bug, is found in association with it.

Tyora ornata (Kirkaldy)

Caroline Islands: Kolonia, Ponape, December 31, 1937; Toloas, Kutua, Truk, July 31, 1939.

A single male, without additional data, was taken in each of these collections.

Leptynoptera sulfurea Crawford

Caroline Islands: Kolonia-Jokaji, Ponape, January 9, 1938; Paliker-Kolonia, Ponape, January 16, 1938; Kolonia, Ponape, January 17, 1938; Gatzapar, Yap, September 1, 1939.

Palau Islands: Akarokuru, Peliliou, August 12, 1939; Kaishar-Ngardok-Ngiwal, Babeldaob, August 15, 1939.

Esaki reports this species as common in Palau, Yap, and Ponape, feeding on young leaves of *Calophyllum Inophyllum* L., gregariously.

Arytaina clara (Tuthill)

Ataenia clara Tuthill, Bernice P. Bishop Mus., Occas. Papers 17: 77, 1942.

Caroline Islands: Kolonia, Ponape, December 31, 1937, and January 1, 1938.

One male and one female constitute the entire collection of this species, which is only known to occur on Ponape. The host plant is unknown.

This and the following related species belong to a large group of species known from the Orient which were assigned to *Arytaina* by Crawford. They are certainly quite far removed from the type species of *Arytaina*, being much nearer *Euphalerus*. I am informed by G. Heslop-Harrison that he is presently revising the many-faceted group that *Arytaina* has become. In the course of such revision he will undoubtedly erect a new genus for this group of species.

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[1] Results of Professor T. Esaki's Micronesian Expeditions, 1936–1940, No. 78. Manuscript received June 28, 1950.

[2] Department of Zoology and Entomology, University of Hawaii.

Arytaina extrema n. sp.

Fig. 1

Length to tip of folded wings, 3.0–3.25 mm.

Color: Dried specimens uniformly brown. When alive probably green, at least abdomen.

Structure: Short pubescence general on body. Head broader than thorax, strongly deflexed. Vertex flat, strongly narrowed anteriorly, blunt protuberance next each eye. Genal processes much below plane of vertex, broad, blunt, one-third as long as vertex, with ring of large stiff setae. Antennae slender, three times as long as width of head. Thorax broad, quite flat. Pronotum large, vertical anteriorly. Forewings broad, slightly over twice as long as wide, broadly rounded apically; venation typical, Cu_1 very strongly arched; pterostigma large, prominent. Legs stout. Metatibiae with large, curved basal spine and 5 black apical spines, 2 single and a cluster of 3.

Male genital segment large, with short pubescence. Proctiger in lateral view slender, produced caudad apically. Forceps about as long as proctiger, slender basally, enlarged apically and produced both caudad and cephalad as figured, inner surface beset with numerous short heavy setae. Female genital segment large, slender; dorsal valve elongate, sinuate, abruptly turned up at apex, with area of minute spines laterally in addition to usual setae; ventral valve long, upturned, acute.

Holotype male, allotype female, and 26 paratypes collected at several localities (Matansha-Calabera, Garapan, Garapan-Sadog Tasi, Tapôcho, Fanagam) on Saipan, Marianna Islands, May 2–6, 1940, Yasu. et Yoshi. Type in author's collection.

This species is very evidently related to *A. clara* (Tuthill) but is readily distinguished by the shorter genal processes, which are much more depressed below the plane of the vertex, the shorter antennae, and details of the genitalia, especially those of the male.

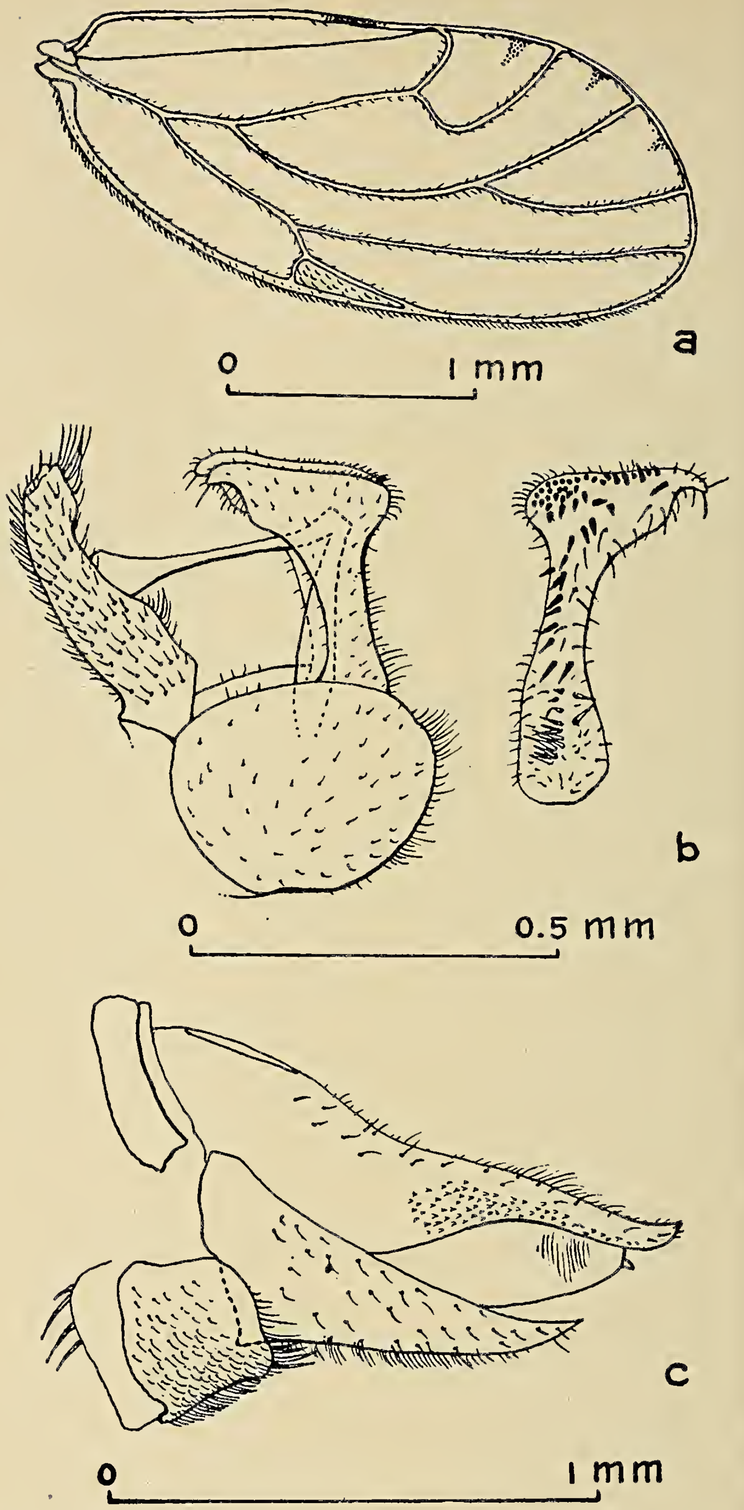

FIG. 1. *Arytaina extrema* n. sp. *a*, forewing; *b*, lateral aspect of male cauda and inner face of clasper; *c*, lateral aspect of female cauda.

Trioza (Megatrioza) vitiensis Kirkaldy

Caroline Islands: Kolonia-Jokaji, Ponape, January 9, 1938; Matalanim, Ponape, January 11, 1938; Matalanim-Nipit, January 12, 1938; Kolonia-Paliker, July 16, 1939.

Esaki notes this widespread species as common on Ponape, where it forms very conspicuous round galls, about the size of a pea, on the leaves of *Eugenia malaccensis* L. It was probably introduced with its host tree.

Trioza suavis n. sp.

Fig. 2

Length to tip of folded wings, 3.5–4 mm.

Color: General color green. Antennae, legs, and margins of thoracic tergites tan. Wings hyaline.

Structure: Head slightly wider than thorax. Vertex short, rounded down both cephalad and caudad, medial suture prominent, posterior ocelli on lateral surface of large protuberances. Eyes large, hemispherical. Genae produced as short, blunt processes, 0.5 as long as width across vertex between eyes. Antennae long and slender, 3.7 times as long as width of head, segment III as long as width of head. Thorax strongly arched. Pronotum vertical. Forewings large, acute apically, 2.6 times as long as wide; Rs short, arched to costa; marginal cells large, medial larger than cubital. Hind wings relatively small but extending well beyond tip of abdomen. Legs stout. Metatibiae with small basal spur, 1 outer and 3 inner large apical spines. Mesopleura and sternum strongly produced. Metacoxae normal.

Male genital segment large. Proctiger strongly produced caudad as figured. Forceps a little shorter than proctiger; in lateral view straight to blunt apex; in caudal view arched to acute black apices; seen dorsally apices notched forming 2 black teeth. Female genital segment small, structure as figured.

Holotype male, allotype female, Palau Islands: Ngardok-Ngarmisukan, Babeldaob, February 11, 1938. Paratypes, 1 male same data as holotype; 2 females, Eimilik-Ngarmisukan, Babeldaob, August 18, 1939; 1 female, Ngarmisukan-Kaishar, Babeldaob, August 14, 1939. Type in author's collection.

Esaki reports this species as forming galls on the leaves of *Ficus* sp. It resembles some of the species assigned to *Megatrioza* by Crawford, especially in the conformation of

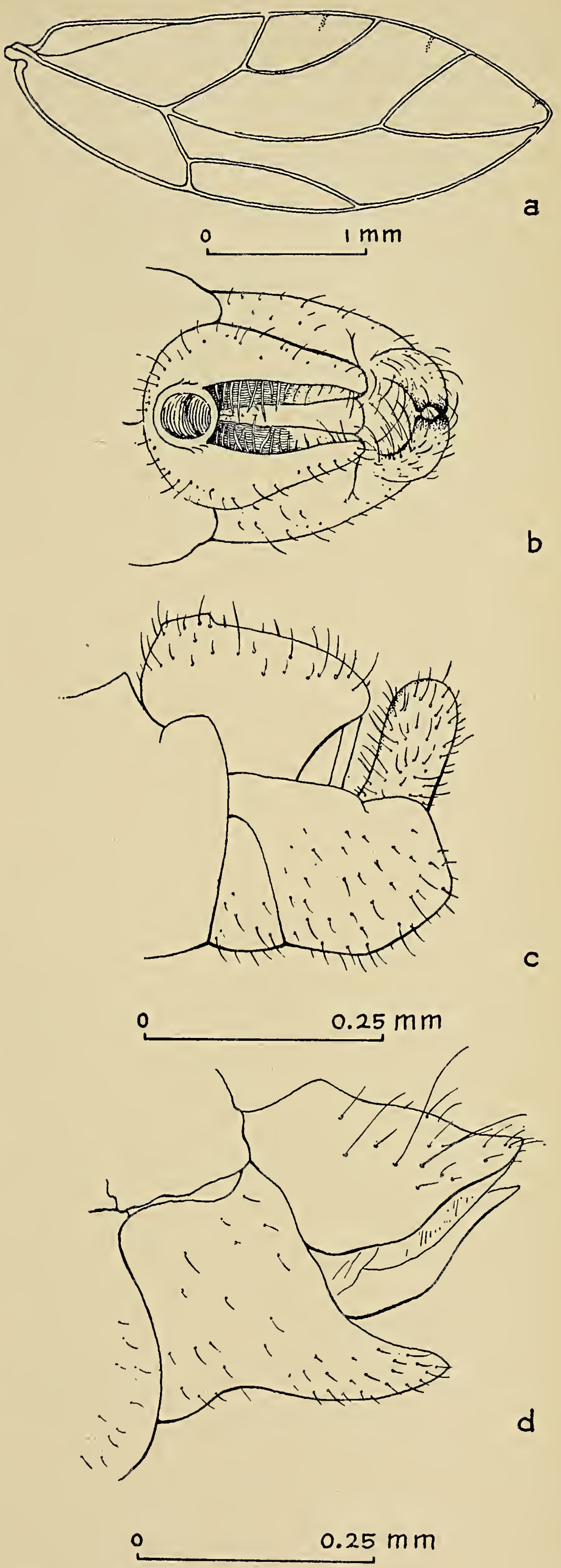

FIG. 2. *Trioza suavis* n. sp. *a*, forewing; *b*, dorsal aspect of male cauda; *c*, lateral aspect of male cauda; *d*, lateral aspect of female cauda.

the genae and in the very large wings. It is perhaps close to *T. vanuae* Kirkaldy, but I have seen no specimens of that species.

Trioza propria n. sp.

Fig. 3

Length to tip of folded wings, 3 mm.

Color: Head and thorax light brown dorsally, remainder of thorax orange. Abdomen chocolate-brown dorsally, yellow ventrally. Genae creamy white. Legs very light tan. Wings milky.

Structure: Almost glabrous, very small setae scattered over body. Head slightly wider than thorax. Postocular area large. Vertex with 2 deep longitudinal sulci, caudal margin sharp, upraised, cephalic margin rounded down, bulgingly produced each side of medial suture. Eyes large, hemispherical. Genal processes short, about one-third as long as vertex, acute, somewhat divergent apically, not completely covering frons at base. Antennae only slightly longer than width of head. Thorax quite flat longitudinally, very strongly arched laterally. Pronotum depressed far below vertex and mesonotum. Forewings about three times as long as wide; branching of basal vein in only specimen at hand not quite trifurcate, media and cubitus with short petiole, Rs smoothly curved to costa, cubital cell larger than medial. Hind wings 0.6 as long as forewings. Metatibiae with basal carina, 1 outer and 2 inner apical spines.

Female genital segment large; ventral valve larger than dorsal, blunt, dorsal acute, darkened apically.

Holotype female, Marianna Islands: Soñg-soñg-Regusa, Pagan, April 28, 1940, Yasu. et Yoshi. Type returned to Esaki.

The genal processes of this unique specimen are reminiscent of those of *Neotriozella* although much shorter. The presence of only two inner apical spines on the metatibiae is rather uncommon in the species known from the Pacific.

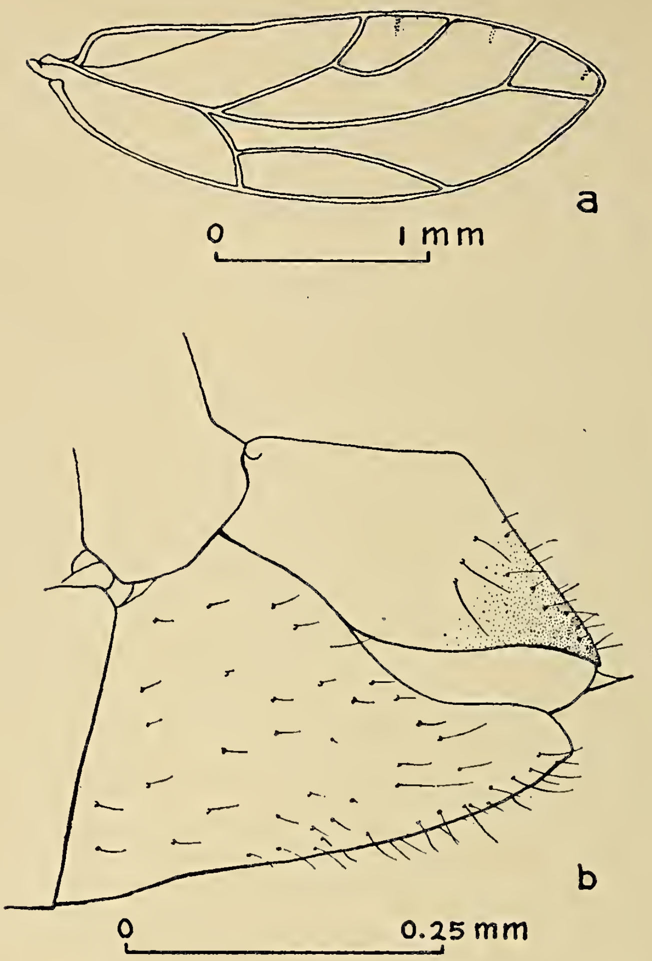

FIG. 3. *Trioza propria* n. sp. *a*, forewing; *b*, lateral aspect of female cauda.

Trioza lyra n. sp.

Fig. 4

Length to tip of folded wings, 3.25 mm.

Color: General color yellow. Incomplete longitudinal brown line medially on mesoscutum and scutellum. Metascutellum nearly white except for large brown Ω-shaped or lyre-shaped spot. Abdomen with narrow brown vitta dorsally, sternites light brown. Eyes red. Antennal segments dark apically.

Structure: Body moderately pubescent throughout. Head as wide as thorax, postocular area small. Vertex emarginate and very abruptly margined caudad, with very prominent discal circular fovea each side of medial suture, latter very prominent, anterior margin bulging, rounded down to genae. Genal processes one-half as long as vertex, broadly rounded. Eyes large, hemispherical. Antennae almost twice as long as width of head. Thorax moderately arched. Pronotum depressed far below vertex and prescutum.

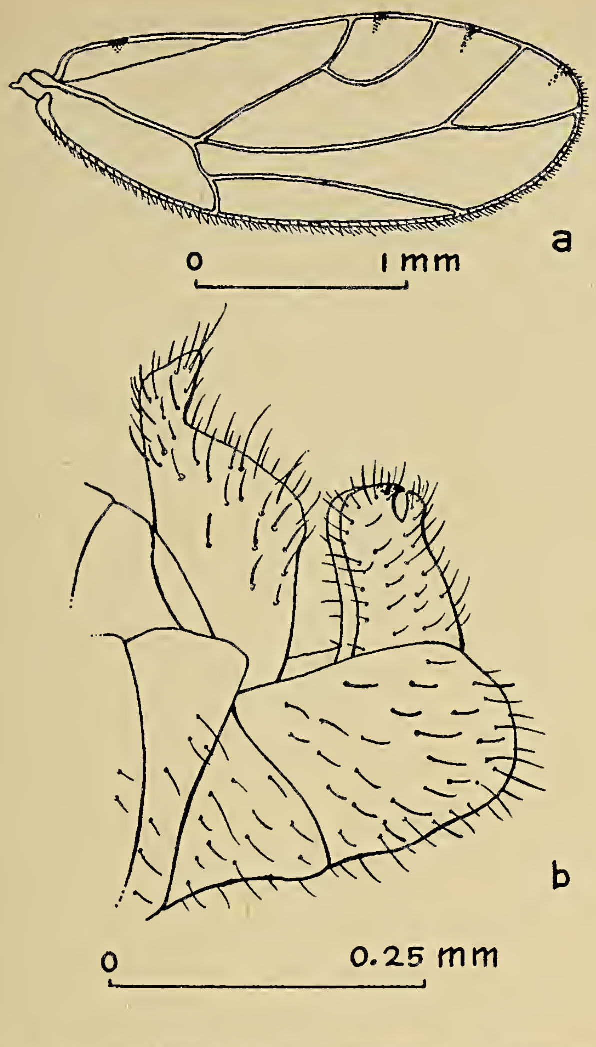

FIG. 4. *Trioza lyra* n. sp. *a*, forewing; *b*, lateral aspect of male cauda.

Forewings 2.5 times as long as wide, rounded apically; Rs rather long, reaching furcation of media, slightly arched to costa, marginal cells about equal. Hind wings two-thirds as long as forewings. Legs rather heavily pubescent. Metatibiae with small basal spur, 1 outer and 2 inner apical spines.

Male genitalia of moderate size. Proctiger long, produced caudad, excavate before apex as figured. Forceps one-half as long as proctiger; in lateral view broad, straight, with deep apical notch forming 2 teeth as figured; in caudal view slender, nearly straight to incurving black tips.

Holotype male, Caroline Islands: Nipit-Ronkiti, Ponape, January 14, 1938. One very teneral female bearing the same data accompanies the male. No information is available as to host plant or habits. Type in author's collection.

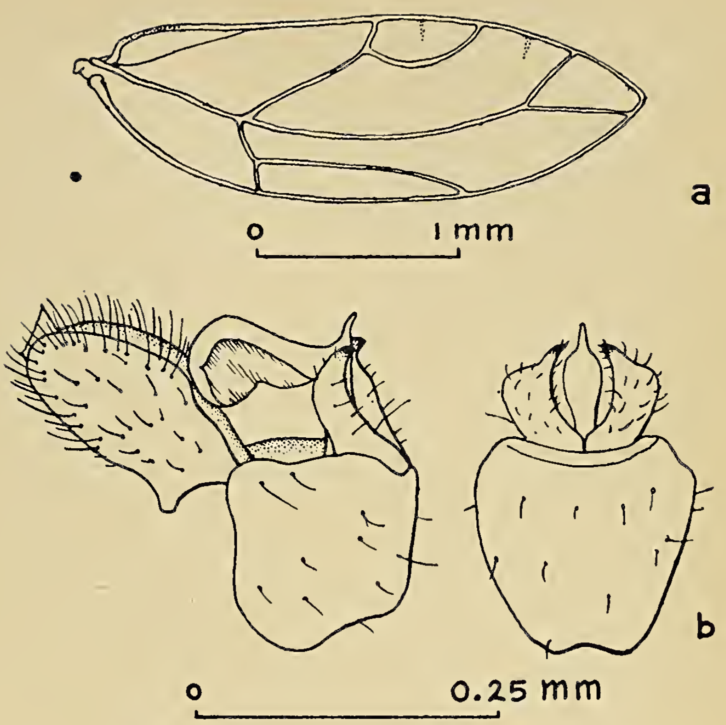

FIG. 5. *Trioza disjuncta* n. sp. *a*, forewing; *b*, lateral and caudal aspects of male cauda.

As with the preceding and following species the relationships of this form are not clear inasmuch as the triozine fauna of the area is so incompletely known.

The specific epithet refers to the marking on the metascutellum.

Trioza disjuncta n. sp.

Fig. 5

Length to tip of folded wings, 3.25 mm.

Color: Uniformly light brown, except eyes red, wings hyaline.

Structure: Long sparse pubsecence on body. Head narrower than thorax. Vertex sharply margined caudally, impressed discally each side of medial suture, bulging anteriorly. Genal processes broadly rounded, slightly over one-half as long as vertex. Antennae short, 1.7 times as long as width of head. Thorax strongly arched. Pronotum not depressed, strongly descending to level of vertex. Forewings slender, sharply angled; three times as long as wide; Rs short, curving to costa, marginal cells equal. Hind wings small, one-half as long as forewings. Metatibiae with serrate basal carina, 1 outer and 3 inner apical spines.

Male genitalia very small, distinctive in structure as figured; aedeagus, especially, different from usual type.

Holotype male, Palau Islands: Ngarumsukan-Kaishar, Babeldaob, August 14, 1939. Type returned to Esaki.

Trioza indigena n. sp.

Fig. 6

Length to tip of folded wings, 3.25 mm. *Color:* Entire dorsum brown, including dorsal portion of folded wings, except for medial yellow spot on pronotum extending as paler line onto vertex and prescutum. Ventral half of body much lighter brown to green.

Structure: Generally pubescent. Head narrower than thorax. Vertex deeply emarginate caudally, prominent discal impression each side of medial suture, at sides smoothly continuous with genae, small protuberances over median ocellus. Antennae far down on genae below line of ocellus, genal processes beyond antennae small, divergent, conical. Antennae slender, 2.5 times as long as width of head. Thorax rather flat for genus. Pronotum vertical, depressed slightly below plane of vertex. Forewings bluntly angulate, 3 times as long as wide, maculate as shown in Figure 6; R_1 very short, Rs arched to costa, marginal cells small, equal. Metatibiae with serate basal carina, 1 outer and 3 inner very large apical spines. Metacoxae somewhat produced anteriorly, meracanthi large, sharp.

Male genital segment small. Proctiger strongly produced caudad. Forceps slightly longer than proctiger; in lateral view slender, somewhat sinuate to black apex (see Fig. 6*b*), in caudal view tapering from broad base, slightly arched, apices not touching. Female genital segment large; dorsal valve slightly longer than ventral, both slender, nearly straight, acute; tips blunt, brown.

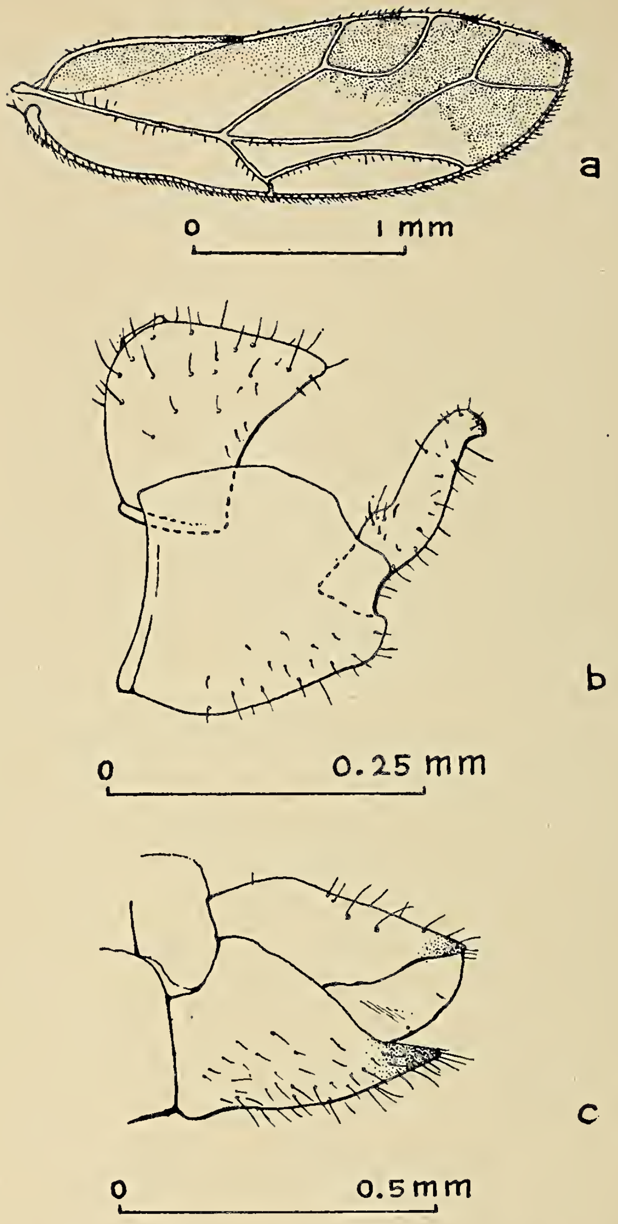

FIG. 6. *Trioza indigena* n. sp. *a*, forewing; *b*, lateral aspect of male cauda; *c*, lateral aspect of female cauda.

Holotype male, allotype female, 7 male and 2 female paratypes, Caroline Islands: Sankakuyama-Kolonia, Ponape, July 15, 1939. Type in author's collection.

This very distinctive species forms small galls on the leaves of *Elaeocarpus Kusanoi* Koidzumi, an endemic tree of Ponape. Dr. Esaki has suggested that perhaps it represents a distinct genus but, although it is markedly different from other species of *Trioza* known from the area, it fits well within the generic limits.

Plant Records from Aur Atoll and Majuro Atoll, Marshall Islands, Micronesia. Pacific Plant Studies 9[1]

HAROLD ST. JOHN[2]

PREVIOUS TO WORLD WAR II, the collections of plants from the Marshall Islands were so few and so local that the flora had not even been well sampled. Since the American occupation of the islands, several botanists have visited various of the islands and made plant collections. Nevertheless, the published data on the flora are very meager and include nothing concerning Aur and Majuro Atolls. The known flora of the Marshall Islands is summarized in Kanehira (1935), though he includes only part of the species recorded from Jaluit by Koidzumi (1915) and, of course, none of those subsequently listed from Jaluit by Okabe (1941).

In December, 1945, the writer was leader of a party of scientists from the University of Hawaii which made a scientific reconnaissance of the Marshalls and other parts of Micronesia. The trip was made possible by the United States Navy, which provided travel by airplane and boat and other facilities.

On December 17, 1945, the party visited Aur Atoll, traveling by sea plane and landing on the lagoon. After ferrying ashore in native canoes, the group had 3 hours available for collection and study of the flora on Tabal, one of the inhabited islets of that atoll.

On December 18 to 19, 1945, by L. C. I. ship, a visit was made in Majuro Atoll to Majuro Islet, a large, inhabited islet on the west side of the lagoon. On both islets native informants were employed, and from them were learned the vernacular names of the plants collected. All native plants and about half of the introduced cultivated ones and half of the adventives were known to the inhabitants by Marshallese vernacular names. These were recorded as they sounded to the observer in American phonetic rendering, just as the vocabulary of Pingelap was recorded. The explanation of the vowel sounds used in both areas is given in the report on the flora of Pingelap by St. John (1948: 99). The decision not to use the alphabet of the current U. S. Navy *Dictionary* (1945) was deliberate, due to dissatisfaction with the complexity of its vowels and the paucity of its consonants. Nearly all of these native vernacular names are here recorded for the first time, since Koidzumi, in his account of the vegetation of Jaluit Atoll, recorded as common names only the Japanese names. Later, Okabe (1941), writing also of Jaluit, recorded 21 Marshallese vernacular names, but only 18 apply to species in the present list and several are obviously different names.

The specimens collected by the University of Hawaii Expedition are deposited in the Bishop Museum, Honolulu.

In the following list the native plants are printed in bold-face roman type, while the adventive weeds and cultivated exotics are in bold-face italics.

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[1] This is the ninth in a series of papers designed to present descriptions, revisions, and records of Pacific island plants. The preceding papers were published as *Bernice P. Bishop Mus., Occas. Papers:* 17(7), 1942; 17(13), 1943; 18(5), 1945; *Amer. Fern Jour.* 35: 87–89, 1945; *Torrey Bot. Club, Bul.* 73: 588, 1946; *Pacific Sci.* 2: 96–113, 1948; 2: 272–273, 1948. Manuscript received February 8, 1950.

[2] Chairman, Department of Botany, University of Hawaii.

POLYPODIACEAE

Asplenium nidus L.

Majuro Atoll, Majuro Islet: epiphytic near base of tree trunks, *St. John 21,410;* "kartĕp."

Nephrolepis acutifolia (Desv.) Christ

Majuro Atoll, Majuro Islet: epiphytic on base of tree trunk, *St. John 21,409;* "anŭmkarere."

Polypodium Phymatodes L.

Aur Atoll, Tabal Islet: on bases of *Cocos* trees, *St. John 21,379;* "kino."

Majuro Atoll, Majuro Islet: observed; called "kino."

More recently this species has been reclassified as *Microsorium Scolopendria* (Burm.) Copeland, in Gen. Fil. 195, 1947. The writer has not yet made the tests necessary to a decision on the validity of the numerous fragments separated from *Polypodium* as genera.

PSILOTACEAE

Psilotum nudum (L.) Griseb.

Majuro Atoll, Majuro Islet: on wet mossy rock, *St. John 21,426;* "mal dŏk" (=to lean toward me), "băng." Rare; the vernacular names known to only a very few old people.

CYCADACEAE

Cycas circinalis L.

Majuro Atoll, Majuro Islet: observed in cultivation in the village; "laugŏk."

PANDANACEAE

Pandanus carolinianus Martelli, Webbia 4(2): 400, tav. XXXIV, figs. 1–3, 1914.

Majuro Atoll: S. E. side, Aug. 26, 1944, *E. H. Bryan, Jr.* "Very good eating—[like] carrot with apricot flavor." First record for the Marshalls. Known only from the type locality on Yap Island. The general name for *Pandanus* is "bŏp."

Pandanus odoratissimus L. f., var. **novo-guineensis** (Martelli) St. John, comb. nov.

P. tectorius Soland. var. *novo-guineensis* Martelli. Webbia 4(2): 413, tav. XLIII, figs. 4–5, 1914.

Kwajalein Atoll, Ennylabegan Island, Aug. 4, 1944, *E. H. Bryan, Jr.* First record in the Marshalls; known previously from Hatzfeldthafen in German New Guinea. The name *P. tectorius* is rejected as being inadequately published.

Pandanus pulposus (Warb.) Martelli, Webbia 4(2): 409, tav. XXXVIII, figs. 1–3, 1914.

P. tectorius Soland. var. *pulposus* Warburg, in Engler's Pflanzenreich IV, fam. 9: 49, 1900.

Aur Atoll, Tabal Islet: tree 7 m.×2 dm., *H. St. John 21,371;* called "kubenan."

Type locality is in the Marshalls: "Radackinseln."; collector, *Chamisso.* Kanehira also listed it from Jaluit.

GRAMINEAE

Cenchrus echinatus L.

Aur Atoll, Tabal Islet: on sand in shade, *St. John 21,376;* called "quărămiyumŭt" (=to slow you down).

Eragrostis amabilis (L.) Wight & Arn.

Aur Atoll, Tabal Islet: common, on sand in shade, *St. John 21,378;* called "wujoĕt" (a name meaning grass, that is, any grass). Also observed on Majuro Atoll, Majuro Islet.

Lepturus repens (Forst.) R. Br.

Aur Atoll, Tabal Islet: tufted, in sand, *St. John 21,373;* "wujoĕt" (= grass).

Saccharum officinarum L.

Majuro Atoll, Majuro Islet: cultivated by house, only one variety, introduced by the Japanese from Kusaie, now rare, *St. John 21,413;* called "to."

Thuarea involuta (Forst.) R. & S.

Aur Atoll, Tabal Islet: creeping, on top of coral sand beach, *St. John 21,374;* called "wujoĕt." Also observed on Majuro Atoll, Majuro Islet.

CYPERACEAE

Cyperus javanicus Houtt.

Majuro Atoll, Majuro Islet: not collected, but observed in a swamp; called "wujoĕt in ion buil" (= marsh grass).

Fimbristylis cymosa R. Br.

Aur Atoll, Tabal Islet: in open sand by shore or in open woods near-by, *St. John 21,399;* called "wujoĭt" (= grass).

PALMAE

Cocos nucifera L.

Aur Atoll, Tabal Islet, and Majuro Atoll, Majuro Islet: not collected, but observed as abundant; called "ni."

ARACEAE

Alocasia macrorrhiza (L.) Sweet

Majuro Atoll, Majuro Islet: observed in cultivation; called "wŏt."

Colocasia esculenta (L.) Schott var. ***antiquorum*** (Schott) Hubb. & Rehd.

Aur Atoll, Tabal Islet: observed in cultivation in one small, wet pit.

Majuro Atoll, Majuro Islet: cultivated in swampy hollow, *St. John 21,416;* "katak" is the general name, but this variety is called "katak Majol," that is, the Marshallese variety. It has the petiole pale green with short purple streaks, the margin purplish; corm 1.5 dm. long with white flesh. The other variety was called "katak in kabelin," or the variety from the west.

Cyrtosperma Chamissonis (Schott) Merr.

Majuro Atoll, Majuro Islet: cultivated in swamp, 2–6 m. tall, petioles smooth, *St. John 21,418;* called "iarătz." Another variety, with spiny petioles, *St. John 21,417*, called "kailĭklĭk" (= spiny).

AMARYLLIDACEAE

Crinum asiaticum L.

Majuro Atoll, Majuro Islet: observed in cultivation in the village; called "kiŭp."

TACCACEAE

Tacca Leontopetaloides (L.) Ktze.

T. pinnatifida Forst.

Aur Atoll, Tabal Islet: planted commonly in shade of trees, *St. John 21,395;* called "magamŭk." Also observed on Majuro Atoll, Majuro Islet: also called "magamŭk."

MUSACEAE

Musa paradisiaca L. subsp. ***sapientum*** (L.) Ktze.

Aur Atoll, Tabal Islet: observed in cultivation; called "keibaran."

Majuro Atoll, Majuro Islet: observed in cultivation; called "kebrang" (the name now obsolete); currently called "benana" (= banana).

MORACEAE

Artocarpus incisus L. f. (corrected from *incisa)*

The general name for all varieties of breadfruit is "me."

Seeded Variety:

Aur Atoll, Tabal Islet: tree 15 m. × 2 dm., cultivated in village, *St. John 21,381;* called "mejuan." Also observed on Majuro Atoll, Majuro Islet.

Seedless Variety:

Aur Atoll, Tabal Islet: tree 20 m. × 1 m., common, especially in village, *St. John 21,380;* called "pădăthadăk."

Ficus tinctoria Forst. f.

Majuro Atoll, Majuro Islet: observed in cultivation; called "tebero" (this name said to be a foreign word).

URTICACEAE

Fleurya ruderalis Gaud.

Majuro Atoll, Majuro Islet: weedy herb in clearings, *St. John 21,407;* called "nenkŭtkŭt (= legs of the turnstone, a bird).

Pipturus argenteus (Forst. f.) Wedd.

Majuro Atoll, Majuro Islet: tree 10 m. × 2 dm., bast fiber used for fishnets and fishline, *St. John 21,412;* called "armai."

AMARANTHACEAE

Gomphrena globosa L.

Majuro Atoll, Majuro Islet: cultivated ornamental, observed in the village; without a vernacular name.

NYCTAGINACEAE

Boerhavia diffusa L. var. **tetrandra** (Forst.) Heimerl.

Aur Atoll, Tabal Islet: trailing in shade, *St. John 21,384;* called "rabĭtchiragai" (=to hold on to a stone).

Bougainvillea spectabilis Willd.

Majuro Atoll, Majuro Islet: observed in cultivation in the village; without a vernacular name.

Mirabilis Jalapa L.

Majuro Atoll, Majuro Islet: observed in cultivation in the village; called "emen aur" (=the fourth hour).

PORTULACACEAE

Portulaca oleracea L.

Majuro Atoll, Majuro Islet: observed by paths.

ANNONACEAE

Annona muricata L.

Majuro Atoll, Majuro Islet: observed in cultivation in the village; called "sauer sharp" (=a pronunciation of sour sop).

LAURACEAE

Cassytha filiformis L.

Aur Atoll, Tabal Islet: vine, over bushes or trees, *St. John 21,392;* called "ganun." Also observed on Majuro Atoll, Majuro Islet; called "kanun."

HERNANDIACEAE

Hernandia ovigera L.

Majuro Atoll, Majuro Islet: tree 15 m. × 2 m., top of beach, *St. John 21,429;* called "bĭngbĭng."

LEGUMINOSAE

Canavalia sericea Gray

Majuro Atoll, Majuro Islet: in sandy woods by shore, *St. John 21,430;* called "marlăp" (=large bush). This species is new to Micronesia. Later collections of it are from Ailinglapalap Atoll, *St. John & Cowan 21,707;* and from Wotje Atoll, *St. John & Cowan 22,076.* These localities are far distant from the nearest known station in Fiji. Its known distribution is shown on the accompanying map (Fig. 1).

It is worthy of note that in the revision of *Canavalia* by Piper and Dunn (1922) the key needs revision. The two well-marked species, *C. galeata* (Gaud.) H. & A. of Hawaii and *C. sericea* Gray of Polynesia, Melanesia, and Micronesia, are incorrectly keyed. They are separated as the first pair of species by the first of the two headings quoted below:

> "1. Pod with two supplementary ribs close to the upper suture.
> Podwith two supplementary ribs 5 mm. or more distant from the upper suture."

To be sure, Piper and Dunn note under their listing of *C. galeata,* "the pods are not described and have not been seen by the writers," but in the previous paragraph they list the reference to Rock, J. F. (*Leguminous Plants of Hawaii* 209, 1920), where the pods of *C. galeata* are described in detail. Collections now in the Bishop Museum, Gray Herbarium, U. S. National Herbarium, and the New York Botanical Garden show that on ripe pods the interval between the supplementary rib and the upper suture measures, in millimeters, 1, 2, 2, 2, 3, 3.5, 4, 4, 4, 4, 5, 6, 8, 9, 12, or from 1–12 mm. Similar measurements for *C. sericea* are: 3, 4, 4, 4, 4, 4, 5, 5, 5, 6, 6, 6, 6, 6, 6, 6, 7, 7, 7, 8, 8, 8, 8, 9, or from 3–9 mm. The key character given by

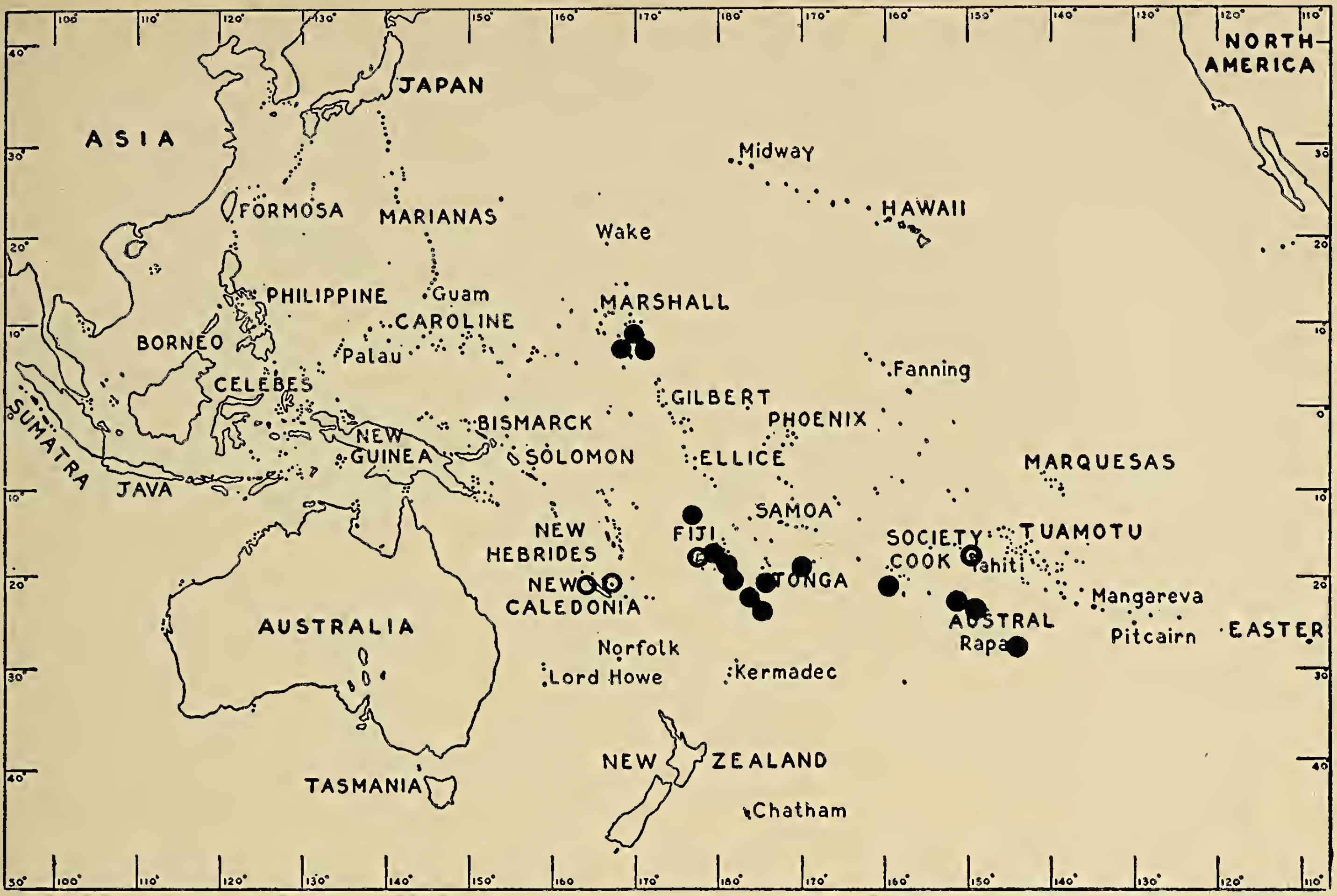

Fig. 1. *Canavalia sericea*, distribution. Round dots for localities of verified collections, reading from east to west: Rapa, Rurutu, Rimatara, Rarotonga, Niue, Nemuka, Eua, Tongatabu, Ongea Ndriti, Koro, Ovalao, Rotuma, Majuro, Wotje, and Ailinglapalap. Circles for published localities, not verified: Tahiti, Viti Levu, Lifou, and Mouac.

Piper and Dunn is (by inference) that this interval is less than 5 mm. for the two species. It is obvious, then, that the key needs revision.

Sophora tomentosa L.

Majuro Atoll, Majuro Islet: young shrub 1 m. tall, on coral sand beach, *St. John 21,428;* called "kullei."

Vigna marina (Burm.) Merr.

Aur Atoll, Tabal Islet: observed.

Majuro Atoll, Majuro Islet: on beach sands or climbing 8 m. on trees, *St. John 21,432;* called "markinejojo."

RUTACEAE

Citrus aurantifolia (Christm.) Swingle

Majuro Atoll, Majuro Islet: tree 8 m. × 2 dm., cultivated commonly in village, introduced by whites since 1900, *St. John 21,415;* called "laim" (=a pronunciation of the English word lime).

SIMARUBACEAE

Suriana maritima L.

Aur Atoll, Tabal Islet: tree 4 m. tall, *St. John 21,386;* "ngiungi."

EUPHORBIACEAE

Acalypha grandis Benth. var. *genuina* Muell. Arg.

Majuro Atoll, Majuro Islet: observed in cultivation in the village.

Euphorbia Atoto Forst.

Aur Atoll, Tabal Islet: tufted, *St. John 21,389;* called "perau." Also observed on Majuro Atoll, Majuro Islet, where called "peiralo."

Euphorbia heterophylla L.

Majuro Atoll, Majuro Islet: observed as a weed in the village; no vernacular name.

Codiaeum variegatum (L.) Bl.

Majuro Atoll, Majuro Islet: observed in cultivation as a hedge in the village. It had no vernacular name.

SAPINDACEAE

Allophyllus timorensis (DC.) Bl.

Aur Atoll, Tabal Islet: tree 8m.×2 dm., *St. John 21,393;* called "kudăk." Also observed on Majuro Atoll, Majuro Islet, where called "kutăt."

TILIACEAE

Triumfetta procumbens Forst. f.

Aur Atoll, Tabal Islet: common in woods near beach, *St. John 21,397;* called "ădăt." Also observed on Majuro Atoll, Majuro Islet, where it has the same vernacular name. The bast fiber is used in plaiting.

MALVACEAE

Hibiscus rosa-sinensis L.

Majuro Atoll, Majuro Islet: observed in cultivation in the village, where called "roz" (=a pronunciation of the English name rose).

Hibiscus tiliaceus L.

Aur Atoll, Tabal Islet: observed near a moist pit. The native name is "loo."

Majuro Atoll, Majuro Islet: tree forming thicket 7 m. tall, *St. John 21,405;* called "lowau." Bast fiber used for mats.

Gossypium barbadense L.

Majuro Atoll, Majuro Islet: observed in cultivation in the village; the vernacular name "kotin" (=a pronunciation of cotton).

Sida fallax Walp.

Aur Atoll, Tabal Islet: observed; called "keo."

Majuro Atoll, Majuro Islet: observed; called "guio."

GUTTIFERAE

Calophyllum Inophyllum L.

Aur Atoll, Tabal Islet: tree 8 m.×3 dm., *St. John 21,372;* called "luĕt," and "luĕs." Also observed on Majuro Atoll, Majuro Islet, where called "luguĕtz."

LYTHRACEAE

Pemphis acidula Forst.

Majuro Atoll, Majuro Islet: tree 8 m.× 3 dm., *St. John 21,427;* called "kungi."

CARICACEAE

Carica Papaya L.

Aur Atoll, Tabal Islet: in common cultivation in the village; called "keinabu."

Majuro Atoll, Majuro Islet: in common cultivation in the village; called "keinapu."

RHIZOPHORACEAE

Bruguiera conjugata (L.) Merr.

Aur Atoll, Tabal Islet: tree 6 m. tall, rare, at edge of swampy excavation in forest, *St. John 21,398;* called "shon."

Majuro Atoll, Majuro Islet: edge of swampy *Cyrtosperma* patch, *St. John 21,406;* called "jung."

COMBRETACEAE

Terminalia litoralis Seem.

Majuro Atoll, Majuro Islet: young tree, branches horizontal, *St. John 21,431;* called "kugung."

ONAGRACEAE

Jussiaea suffruticosa L. var. ***ligustrifolia*** (HBK.) Griseb.

Majuro Atoll, Majuro Islet: observed as a weed in wet garden plots; without a vernacular name.

ARALIACEAE

Nothopanax Scutellaria (Burm. f.) Merr.

Majuro Atoll, Majuro Islet: observed as a common hedge in the village; without a vernacular name.

Polyscias Guilfoylei (Bull) Bailey

Majuro Atoll, Majuro Islet: observed in cultivation in the village as a hedge.

UMBELLIFERAE

Centella asiatica (L.) Urban

Aur Atoll, Tabal Islet: sandy flat by house, introduced weed in village, *St. John 21,375;* called "nargo." Also observed on Majuro Atoll, Majuro Islet, where called "marigo."

APOCYNACEAE

Ochrosia oppositifolia (Lam.) K. Schum.

O. parviflora (Forst.) Henslow

Aur Atoll, Tabal Islet: tree 15 m.×2 dm., *St. John 21,388;* called "kujebara."

Plumeria acuminata Ait.

Aur Atoll, Tabal Islet: ornamental trees, observed in cultivation in the village; called "mei ria."

Majuro Atoll, Majuro Islet: common ornamental tree, cultivated; called "meria." The vernacular names are contractions of *Plumeria.*

ASCLEPIADACEAE

Asclepias curassavica L.

Majuro Atoll, Majuro Islet: observed, cultivated as an ornamental in the village; called "ialu" (=a pronunciation of yellow).

CONVOLVULACEAE

Ipomoea Batatas L.

Majuro Atoll, Majuro Islet: cultivated, rare, introduced by the Germans. Tuber 1.5 dm. long, flesh white, *St. John 21,414;* called "juweet potato" (=sweet potato).

Ipomoea gracilis R. Br.

Majuro Atoll, Majuro Islet: vine, climbing 2–3 m., *St. John 21,411;* called "marginejojo."

Ipomoea pes-caprae (L.) Roth

Majuro Atoll, Majuro Islet: common on or near the beaches; called "marginejojo."

Ipomoea tuba (Schlecht.) Don

I. grandiflora sensu Jacq., non L. f.

Aur Atoll, Tabal Islet: trailing or climbing high on trees, *St. John 21,385;* called "marabele" (=white man's or foreign necklace). Also observed on Majuro Atoll, Majuro Islet; called "marabele."

BORAGINACEAE

Cordia subcordata Lam.

Majuro Atoll, Majuro Islet: tree 10 m.× 4 dm., wood used for timber, *St. John 21,408;* called "kono."

Messerschmidia argentea (L. f.) I. M. Johnston

Tournefortia argentea L. f.

Aur Atoll, Tabal Islet: tree 7 m.×2 dm., common near outer beach, *St. John 21,390;* called "krĭn." Also observed on Majuro Atoll, Majuro Islet, where called "kurĭn."

VERBENACEAE

Premna integrifolia L.

Majuro Atoll, Majuro Islet: native tree, observed; called "kar."

LABIATAE

Ocimum sp.

Majuro Atoll, Majuro Islet: aromatic herb, observed in cultivation; called "katarin" (=Catharine).

ACANTHACEAE

Hemigraphis reptans (Forst.) T. Anders.

Majuro Atoll, Majuro Islet: trailing in shade, only in village, *St. John 21,433.* It has no native name and was probably introduced, perhaps by the natives.

RUBIACEAE

Guettarda speciosa L.

Aur Atoll, Tabal Islet: tree 8 m.×2 dm., *St. John 21,387;* called "wudilonaro" (=flower of the bush).

Majuro Atoll, Majuro Islet: observed; called "wŭt."

Hedyotis biflora (L.) Lam.

Oldenlandia biflora L.

Majuro Atoll, Uliga Islet: erect, forming colonies 1 m. in diameter, *St. John 21,370.*

Ixora carolinensis (Val.) Hosokawa var. *typica* Fosberg

Majuro Atoll, Majuro Islet: observed. Apparently cultivated; called "gajiru."

Morinda citrifolia L.

Aur Atoll, Tabal Islet: shrub 3 m. tall, *St. John 21,394;* called "nin." Also observed on Majuro Atoll, Majuro Islet; called "nin."

CUCURBITACEAE

Cucurbita Pepo L.

Majuro Atoll, Majuro Islet: observed, commonly cultivated for food, near the houses; called "pămki" (=a pronunciation of pumpkin).

Lagenaria siceraria (Molina) Standl.

L. leucantha (Duch.) Rusby

Aur Atoll, Tabal Islet: cultivated near house, *St. John 21,377;* called "pangi" (=a pronunciation of pumpkin). Introduced by the members of the Rurick voyage under Capt. Kotzebue in 1817, and perhaps not previously cultivated by the natives.

GOODENIACEAE

Scaevola frutescens (Mill.) Krause

Aur Atoll, Tabal Islet: shrub, mostly near the sea beach, *St. John 21,391;* called "gunnat." Also observed on Majuro Atoll, Majuro Islet; called "kunnat."

COMPOSITAE

Wedelia biflora (L.) DC.

Aur Atoll, Tabal Islet: sprawling shrub, *St. John 21,396;* called "marijĕtch." Also observed on Majuro Atoll, Majuro Islet; called "marijatch."

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ST. JOHN, HAROLD. 1948. Report on the flora of Pingelap Atoll, Caroline Islands, Micronesia, and observations on the vocabulary of the native inhabitants: Pacific Plant Studies 7. *Pacific Sci.* 2: 96–113, map, figs. 1–9.

UNITED STATES NAVY, 14th NAVAL DISTRICT, DISTRICT INTELLIGENCE OFFICE. 1945. *Marshallese-English and English-Marshallese dictionary.* 1: xxx+136 pp.; 2: 1–121.

Note on the Feeding Habits of the Giant White Marlin of the Pacific[1]

On June 22, 1950, an 851-pound white or silver marlin, *Makaira marlina* (Jordan and Hill), was brought into the Kyodo Fishing Co., Ltd., at Honolulu as part of the commercial catch of the long-line fishing boat "Monarch." The specimen had been cut in two about midway between the operculum and the caudal fin as is common practice aboard local long-line vessels to facilitate stowage of large fish. It was noted in this particular specimen, however, that the stomach and part of the large intestine had been torn appreciably, leaving a sizable gap in the abdominal cavity. According to information given by Shigeo Yamaguchi, captain of the fishing boat, the marlin was caught on one of the long lines, at a depth of about 60 fathoms, during fishing operations off Hana, Maui. When the fish was brought aboard it was observed that the abdomen was abnormally swollen, and upon cutting the fish for stowage, a big-eyed tuna (*Parathunnus sibi*) was found lodged in the stomach. The tuna had been caught on the long line first, for the hook still was set in the tuna's mouth when the specimen was removed from the stomach of the marlin. The marlin evidently had found the hooked tuna an easy prey and swallowed it head-first. It appears that the latter is a common feeding practice of the large spearfishes as noted by Nakamura (*Science of the Seas* [Kaiyo no Kagaku] 3(10), October, 1943). The tuna was removed from the stomach, and, since little digestive action had taken place, it was stowed as part of the catch.

When brought into the market, the tuna was found to weigh 158 pounds, although the anterior portion of the head was missing, having been cut off when the marlin was sectioned. It measured 1373 mm. in length from the posterior margin of the orbit to the cartilaginous part of the median caudal rays. From the two pieces of the marlin, an approximate length of 2994 mm. was obtained, as measured from the naris anteriorly to the median rays of the caudal fin posteriorly.

Although it has been previously noted (Nakamura, *op. cit.*) that the giant spearfishes can easily swallow adult skipjack, this is believed to be the largest single food item recorded for this group of fishes.—*Fred C. June, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, Honolulu, Hawaii.*

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[1] Published by permission of the U. S. Fish and Wildlife Service.

News Notes

The following publications of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, Tokyo, Japan, have been received. Each report includes a list of all of the reports previously published, their distribution, and rules for obtaining them.

Reconnaissance Soil Survey of Japan. Nagoya Area, by Ellis J. Kohler. Report No. 110-F. 76 pp., 6 figs., 20 tables, 9 maps.

Metallurgical Plants of Japan, by Joseph E. Hersch and Robert L. Kidd. Report No. 137. 71 pp., 14 figs., 20 tables.

Japanese Offshore Trawling, by Francois Bourgois. Report No. 138. 60 pp., 31 figs., 14 tables.

Bentonite and Bleaching Clay in Japan, by Donald E. Lee. Report No. 139. 28 pp., 9 figs., 4 tables.

Safety in Japanese Coal Mines, by Charles S. Merriam. Report No. 140. 32 pp., 24 figs.

Fisheries Research Program of Japan, by Willis H. Rich. Preliminary Study No. 42. 40 pp. Mimeographed.

Management of Private Coniferous Forests of Japan, by Joseph C. Kircher and Albert K. Dester. Preliminary Study No. 43. 30 pp., 6 figs. Mimeographed.

Refractory Silica Resources of Japan, by Hideshiro Hasegawa. Preliminary Study No. 44. 29 pp., 3 figs., 15 tables. Mimeographed.

Forest Insect Control in Japan, by R. L. Furniss. Preliminary Study No. 45. 32 pp., 1 fig. Mimeographed.

Scientists in Honolulu recently enjoyed four stimulating lectures given by Dr. Linus J. Pauling, head of the Department of Chemistry and Chemical Engineering and Director of the Crellin Laboratories at the California Institute of Technology, Pasadena, California. Dr. Pauling discussed the structure of protein molecules in general and of hemoglobin in particular, the nature of antibodies and of antigen-antibody reactions, and the valence of metals in intermetallic combinations.

The Secretary-General of the South Pacific Commission, Mr. W. D. Forsyth, has informed Commissioners of his wish to relinquish the post of Secretary-General and to return to Australia before June 30 of this year. His extended leave from the Australian External Affairs Service expires this year. During Mr. Forsyth's term as Secretary-General the main lines of organization have been laid down, the work program launched, a full cycle of meetings completed of the Commission and its auxiliary bodies (the Research Council and the South Pacific Conference), staff recruited, and the headquarters of the Commission established at the permanent site at Anse Vata, Noumea.—*South Pacific Commission Press Release.*

Dr. J. Harlan Johnson, Professor of Geology at the Colorado School of Mines, is currently collecting and studying coralline algae in the Trust Territory and Okinawa for the island mapping program of Pacific Geologic Surveys Section, Military Geology Branch, United States Geological Survey. While at the Tokyo office headquarters, he will confer with Japanese specialists in this field. Dr. Johnson plans to be in the Pacific Area for four months during this summer and, following his return to Colorado School of Mines, will continue systematic study of fossil algae collections and Pacific Island limestones.

Books Received:

FREEMAN, OTIS W., Editor. *Geography of the Pacific.* ix + 573 pp., 156 figs. John Wiley & Sons, Inc., New York, and Chapman and Hall, Limited, London. 1951. $10.00.

CARSON, RACHEL L. *The Sea Around Us.* vii + 230 pp. Oxford University Press, New York. 1951. $3.75.

ALLAN, JOYCE. *Australian Shells.* xix + 470 pp., 44 pls., 112 figs. Georgian House, Melbourne. 1950. $7.50.

pasted on proper page, and point of insertion should be clearly indicated.

Original copy and one carbon copy of manuscript should be submitted. The author should retain a carbon copy. Although due care will be taken, the editors cannot be responsible for loss of manuscripts.

Introduction and summary. It is desirable to state the purpose and scope of the paper in an introductory paragraph and to give a summary of results at the end of the paper.

Dictionary style. It is recommended that authors follow capitalization, spelling, compounding, abbreviations, etc., given in *Webster's New International Dictionary* (unabridged), second edition; or, if desired, the *Oxford Dictionary.* Abbreviations of titles of publications should, if possible, follow those given in U. S. Department of Agriculture *Miscellaneous Publication 337.*

Footnotes. Footnotes should be used sparingly and never for citing references (see later). When used, footnotes should be consecutively numbered by superior figures throughout the body of the paper. Footnotes should be typed in the body of the manuscript on a line immediately below the citation, and separated from the text by lines running across the page.

Citations of printed sources. All references cited should be listed alphabetically by author at the end of the paper, typed double-spaced. References to books and to papers in periodicals should conform to the following models:

BATZO, RODERICK L., and J. K. RIPKIN. 1849. *A treatise on Pacific gastropods.* vii + 326 pp., 8 figs., 1 map. Rice and Shipley, Boston.

CRAWFORD, DAVID L. 1920*a*. New or interesting Psyllidae of the Pacific Coast (Homop.). *Ent. News* 31 (1): 12–14.

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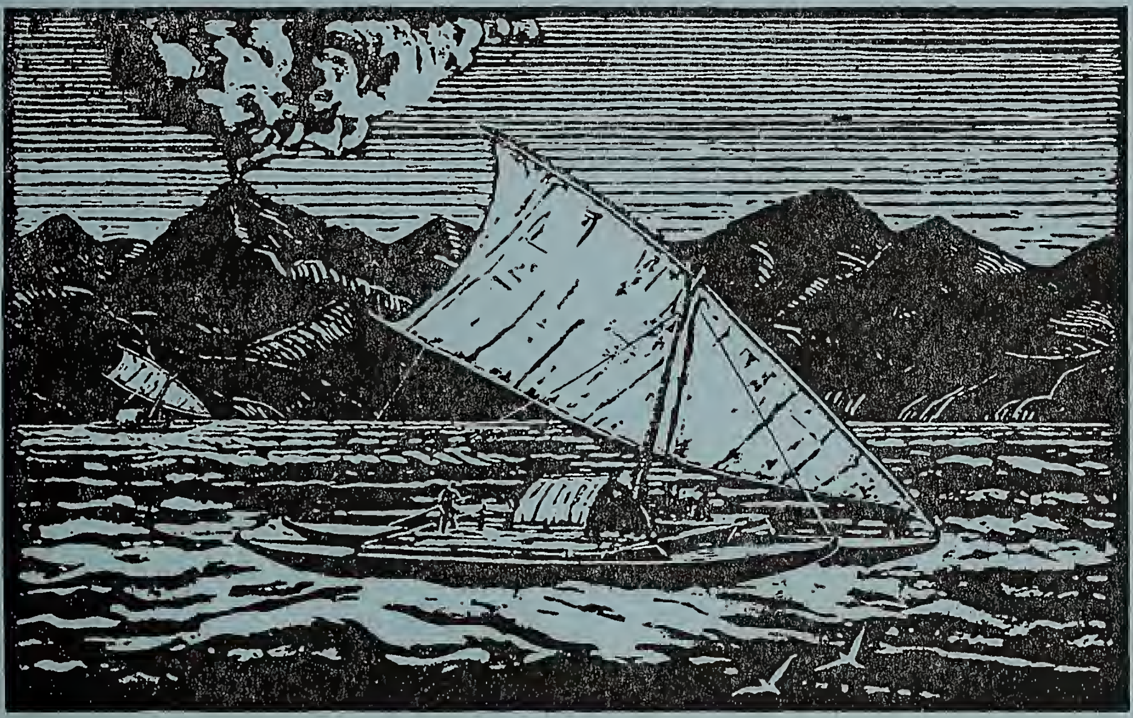

HAWAII MARINE LABORATORY ISSUE: Hiatt — *The Hawaii Marine Laboratory* ● Gosline—*Osteology and Classification of Ophichthid Eels of Hawaii* ● Tester — *Distribution of Eggs and Larvae of* Stolephorus purpureus ● Hiatt — *Food and Feeding Habits of* Stolephorus purpureus ● Matthews — *Origin, Development, and Nature of the Spermatophoric Mass of the Spiny Lobster* ● Haneda — *Luminescence of Some Deep-sea Fishes* ● Hartman — *Fabricinae in the Pacific* ● Bick — *Ecology of Mosquito Larvae of New Guinea* ● NEWS NOTES ● INDEX

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DEC 1 8 1951

The Hawaii Marine Laboratory[1]

ROBERT W. HIATT[2]

INTRODUCTION

THE COCONUT ISLAND BRANCH of the Hawaii Marine Laboratory was officially opened on April 21, 1951, with an exhibit of research in progress and equipment utilized in the marine sciences. The Hawaii Marine Laboratory is an integral part of the University of Hawaii and consolidates under one name the long-established Marine Biological Laboratory at Waikiki Beach, the biological laboratories devoted to marine sciences on the main campus of the University, and the newly constructed branch at Coconut Island. The Laboratory operates for both teaching and research, with the Waikiki branch and the classrooms and laboratories on the main campus of the University devoted primarily to instruction, and the Coconut Island branch devoted exclusively to research. These new facilities greatly enhance the effectiveness of both the academic program in marine and fishery biology leading to the bachelor's, master's, and doctor's degrees, and the research program in marine sciences of the graduate students and regular staff. Physical separation of instruction and research has now been achieved so that neither interferes with the other. A well-integrated instructional program in marine biology may now be carried out throughout the year at the reef edge at the Waikiki branch, while research projects may proceed without interruption throughout the year at the Coconut Island branch.

The generous loan of unexcelled facilities for marine research by Messrs. Allan Chase, Edwin Pauley, Harold Pauley, Poncet Davis, and Samuel Mosher made it possible to establish the Coconut Island branch. Through funds provided by Mr. Edwin Pauley and the University of Hawaii, this Laboratory and associated ponds and aquaria have been completed and put into operation.

The Laboratory operates throughout the year, but more space is available for visiting investigators during the regular academic year than during the summer period.

Since the Coconut Island branch has been established for strictly research purposes, only persons prosecuting some specific study leading to eventual scientific publication, or an assistant of such a person, will be accommodated. Naturally, staff members of the University of Hawaii will have priority for available space. A cooperative agreement entered into by the University of Hawaii and the University of California for the purposes of mutual assistance in marine research in the central Pacific provides second priority to interested members of the staff of the latter institution. The remaining space is available to other marine scientists. All requests for space must be made on an application form available from the Director. Visiting investigators are welcome and all possible aid will be provided them by the staff of the Laboratory. Such laboratory facilities and housing as are available to visiting investigators bear no fee, except where expendable supplies are concerned. A brochure describing the Laboratory and the regulations for visiting investigators is available from the Director.

COCONUT ISLAND BRANCH

Location: Coconut Island, known to Hawaiians as Moku-o-loe, is situated in the pro-

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[1] Contribution No. 8, Hawaii Marine Laboratory.

[2] Department of Zoology and Entomology, University of Hawaii. Manuscript received June 15, 1951.

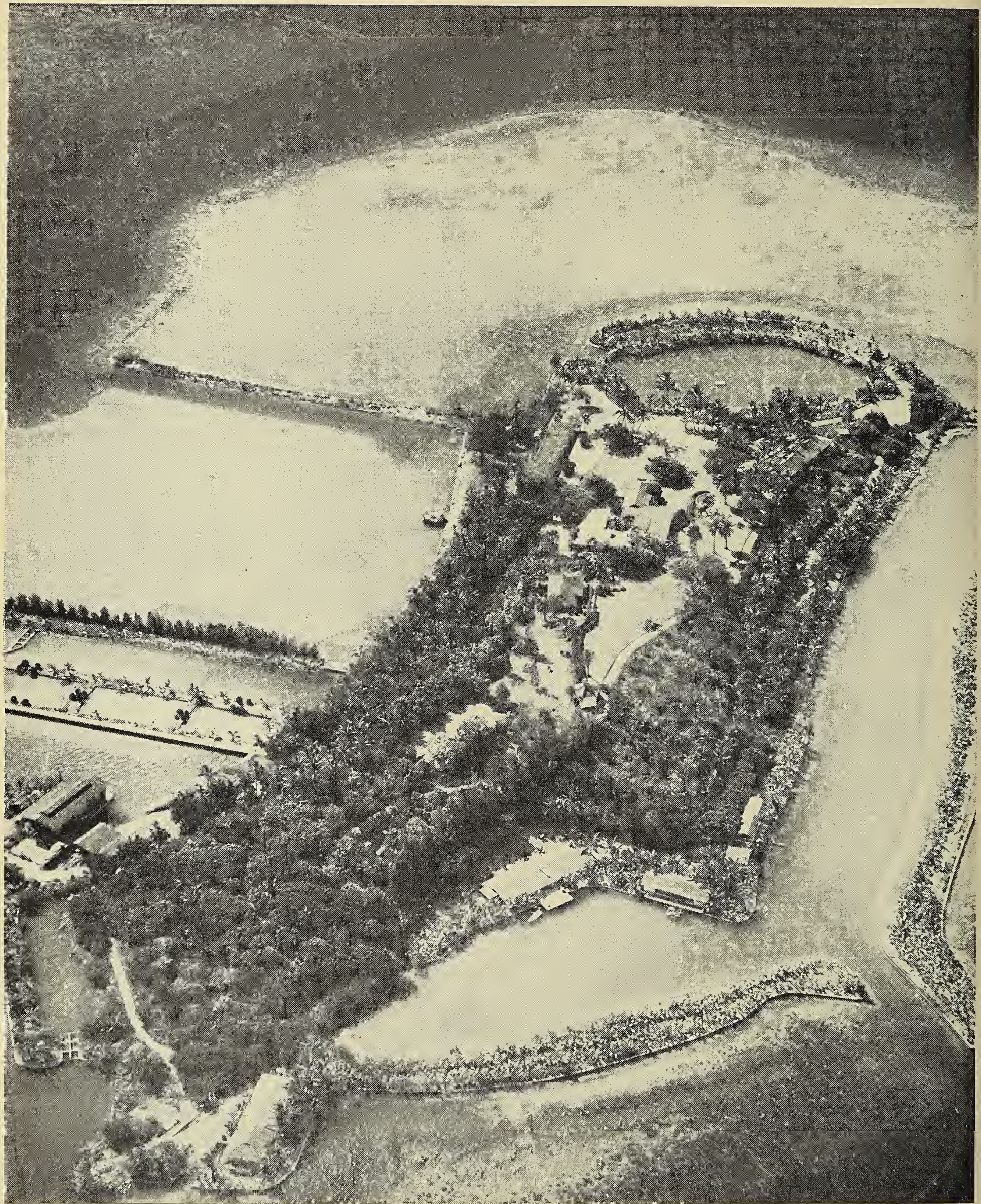

FIG. 1. Aerial view of Coconut Island, showing the Marine Laboratory (lower center) and the tidal pools (middle left).

tected waters of Kaneohe Bay, about 15 miles from Honolulu, and about 200 yards off the windward shore of Oahu (Fig. 1). Containing a total of 18 acres of land, this verdant island is surrounded by numerous lagoons and pools dredged in the fringing reef. Kaneohe Bay, about 15 square miles in extent, opens broadly to the sea over a protective, elevated reef. The northeast trade winds sweep directly into the bay, thus forcing a rapid exchange of the bay and oceanic waters, which provides for ranges of salinity varying from brackish conditions close to stream mouths to almost normal ocean conditions in the more open areas.

Much of the peripheral region of the bay, especially near the mouths of intermittent streams, is muddy. The organic content of these sandy and muddy areas is high, and it supports an extensive marine fauna. The central part of the bay consists of many channels of varying widths surrounding coral platforms which reach the surface of the water at low tide. Each coral platform is fringed by an extensive growth of corals, principally *Porites compressa* and species of *Montipora*, comprising the finest development of coral growth in the Hawaiian Islands. The eroding tops of these coral platforms contain isolated coral heads interspersed with a fine, silty sand composite. The sides of the channels below 4 fathoms and the bottoms of the channels at an average of 7 fathoms consist of very fine silt. There are many coral heads and intervening sandy areas on the fringing reef platform surrounding Coconut Island, thus providing one of the richest collecting grounds in Hawaii. Contributing greatly to the varied ecological situations in the vicinity of Kaneohe Bay are the true oceanic conditions found just outside the bay, within half an hour's boat trip from the Laboratory.

Fauna and flora: Hawaii is situated at the extreme eastern periphery of the richest faunal area known, the Indo-Pacific. Over 2,000 species of invertebrates and over 500 species of fish inhabit the reef and inshore areas. The Laboratory and its environs offer ideal facilities for studies on all phases of the biology of tropical and subtropical fish, turtles, and invertebrates. Comparatively little is known about the biology of such animals so there is great latitude in the selection of research problems. The zooplankton of the bay waters and the neritic waters just outside the bay is exceedingly varied and abundant in contrast with the oceanic waters farther from shore. The finest oceanic bird rookery in the Hawaiian Archipelago, excepting some of the Leeward Hawaiian Islands, is located just outside Kaneohe Bay on the islet of Moku Manu: a half-hour boat trip from the Laboratory places the observer upon an unparalleled outdoor laboratory for studies on several species of terns, shearwaters, petrels, boobies, and frigate birds.

Hawaiian shores abound in algae of all major groups. Especially abundant are chlorophycean genera such as *Ulva*, *Cladophora* (a variable genus with many representatives), *Caulerpa*, *Codium*, and *Halimeda*. The last four genera offer special possibilities as subjects for physiological research, *Cladophora* because it is large-celled and filamentous, *Caulerpa* and *Codium* because they are unicellular, and the unicellular *Halimeda* because it produces abundant calcareous deposits. Among the Phaeophyceae prominent genera are *Ectocarpus*, *Sargassum*, *Padina*, and *Stictyota*. The red algae are represented by many genera, perhaps the most abundant of which are *Laurencia*, *Rhodymenia*, *Liagora* (mostly calcareous), and the corallines. The agariferous genus *Gelidium* is of special interest. The blue-green algae and the diatoms are, of course, abundant.

Property: The buildings, ponds, docks, and repair facilities occupy the leeward fringe of Coconut Island. In addition to the laboratory itself, there are a residence hall, net house, dock, marine railway, six tidal ponds of varying dimensions and depths (Fig. 2), a battery of large glass-fronted aquaria, and five large partially sunken concrete tanks

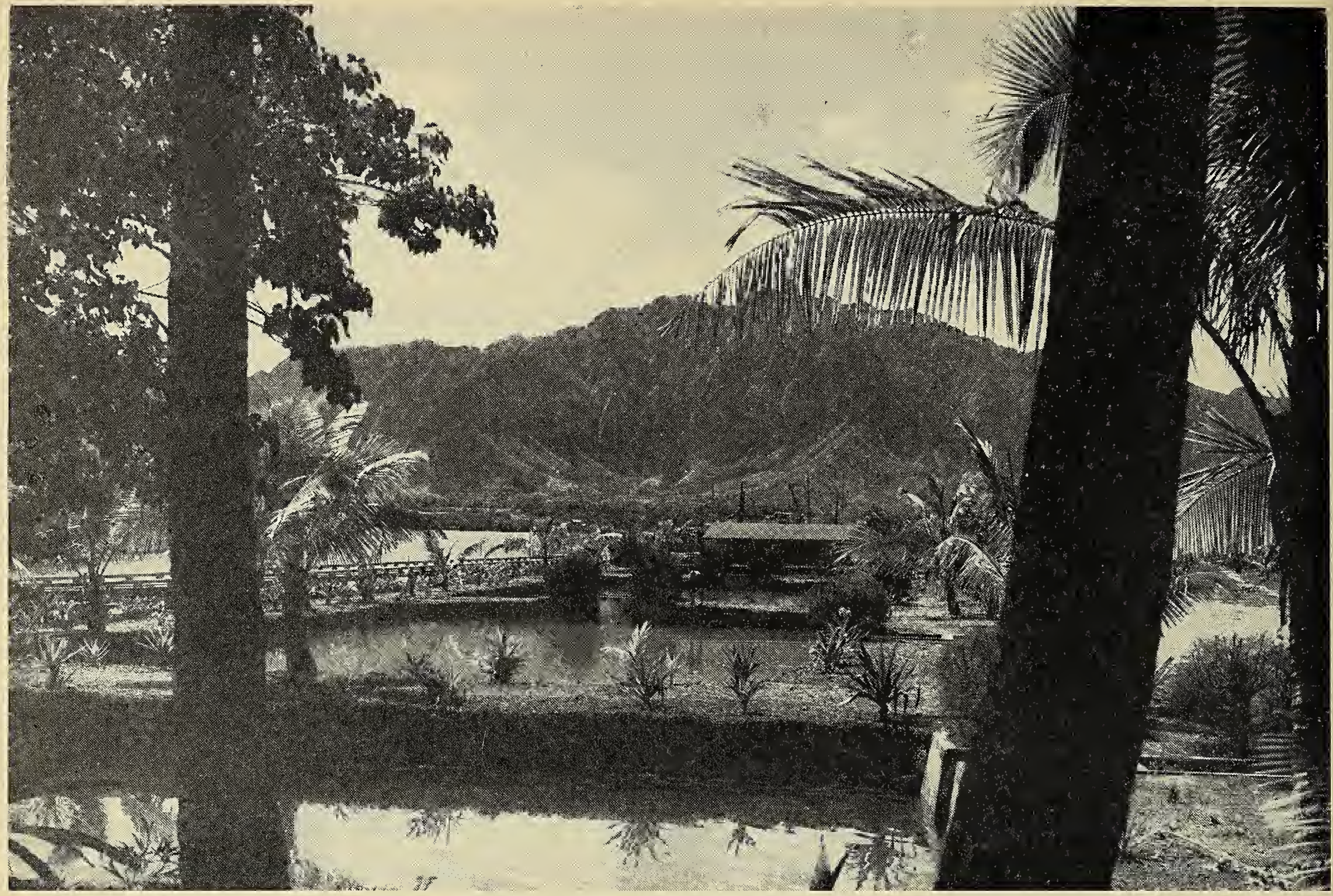

FIG. 2. View of some tidal ponds.

with an aggregate capacity of 20,000 gallons. The aquaria and tanks are provided with circulating sea water by a pumping plant separate from that which supplies the system in the laboratory building.

Laboratory and auxiliary buildings: The laboratory building (Figs. 3, 4) faces southeast and borders a large dredged lagoon. The dock is connected to the laboratory structure with a concrete lanai, thus facilitating the transfer of living specimens from the live well of the laboratory's research vessel, the *Salpa*, to the aquarium tables of the laboratory just 30 feet away. Collecting gear and supplies may also be transferred readily to and from the *Salpa*.

The building contains two large laboratories, one for general biological work and one for physiological research, and two smaller general-purpose laboratories (Fig. 5). Fluorescent overhead lights assure adequate illumination. Four to six investigators may be conveniently located in each of the larger laboratories and two in each of the smaller laboratories. In addition to the laboratories there are a work shop, a darkroom, three storerooms, a collection room, and a long concrete lanai on which the aquarium tables are located, thus keeping the sea water out of the laboratories proper. The remainder of the laboratory building consists of living quarters with two large bedrooms, one large dormitory, a kitchen, a combination dining and living room, and bathrooms.

Additional living quarters are located in a second building. These consist of two large bedrooms, one smaller bedroom, bathroom, and living quarters for the caretaker. An electrically operated marine railway which can handle all the smaller craft, and a large storage house for pond screens and other large equipment, complete the present plant.

Laboratory equipment: Running sea water with a salinity of about 35 to 36 parts per thousand is distributed to both the large outdoor aquaria and to the smaller salt-water

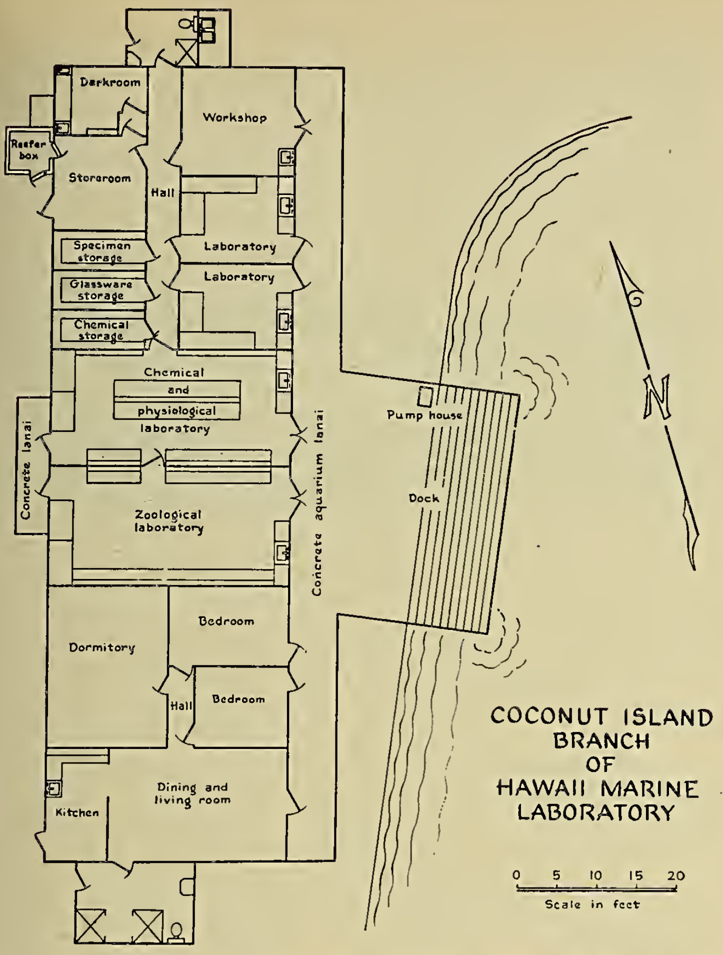

FIG. 3. Floor plan of the laboratory building and dock.

tables on the lanai outside the laboratories. Pumps and motors are arranged in duplicate for each system, with a timer switch which automatically alternates the units. There is no storage or recirculation of sea water, but rather a continuous pumping mechanism. The large pumps are made of cast iron while the lines and valves are of transite, antimony-free lead, and hard rubber. The unit supplying sea water to the smaller laboratory aquaria consists of stainless steel pumps, lead pipes, and hard rubber cocks. The sea water delivered is thus free from contaminants and suitable for the most critical embryological studies. The six large tidal ponds provide unusual space for holding live material, either of small or large size.

Laboratories are supplied with hot and cold running fresh water, 110- to 115-volt alternating current, and bottled-gas outlets. Vacuum and pressure are achieved by portable pump

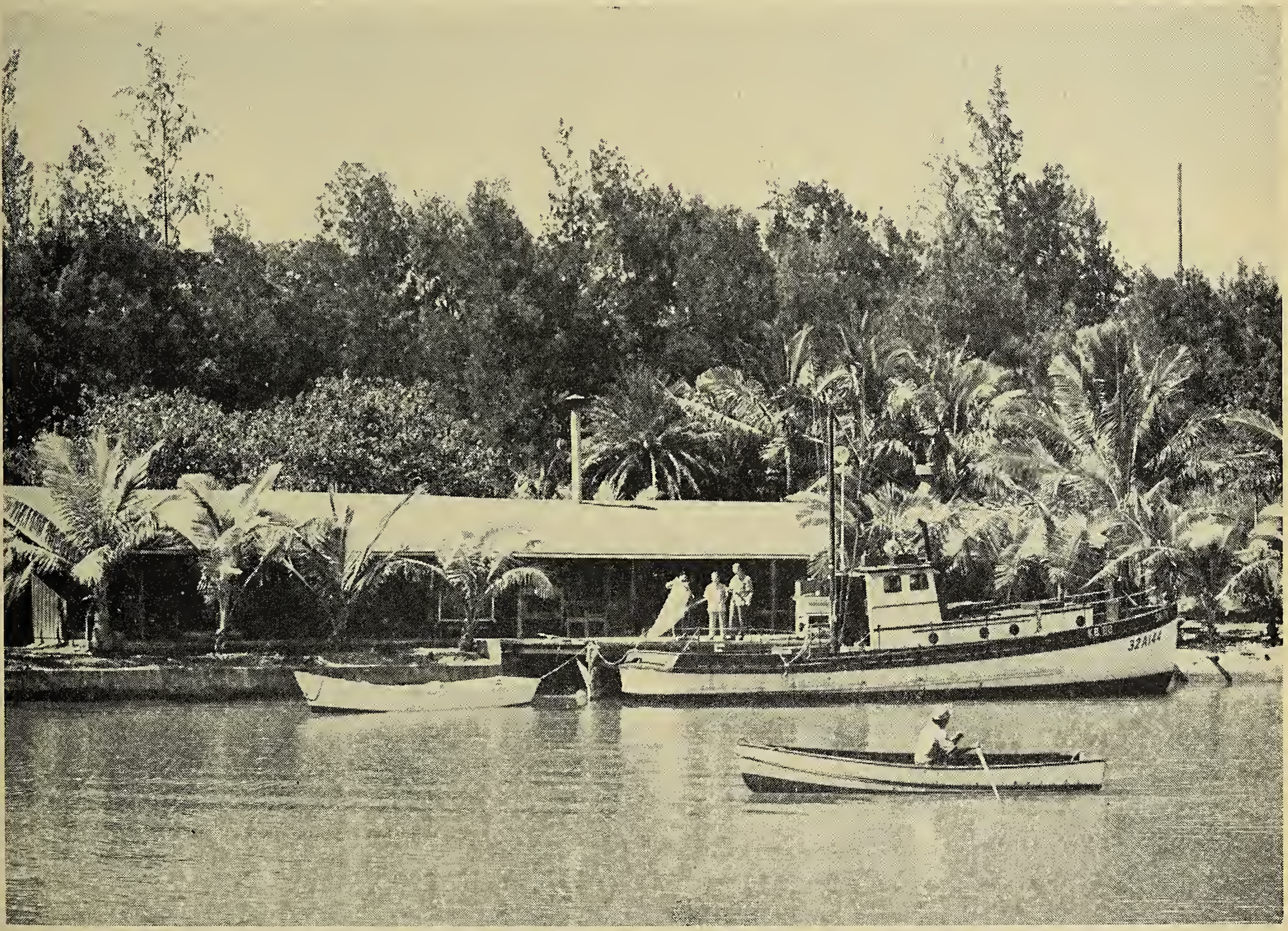

FIG. 4. View of the laboratory building.

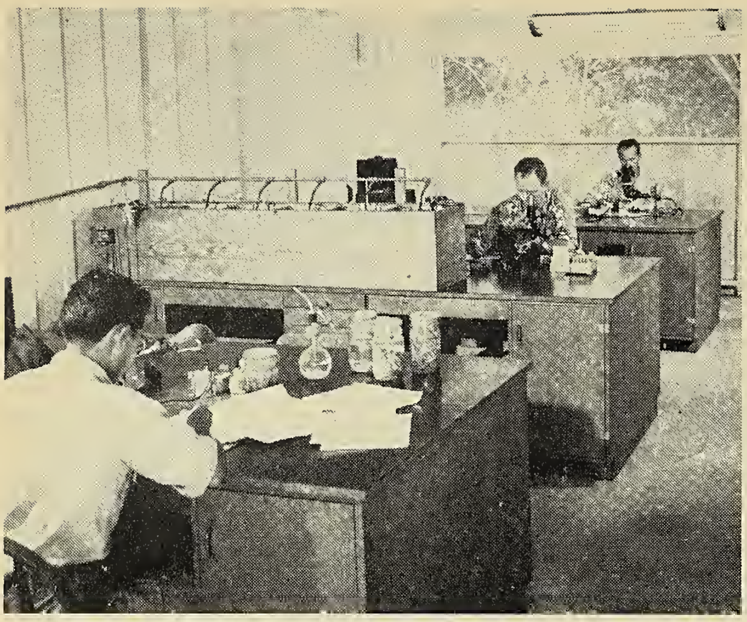

FIG. 5. Interior of a biology laboratory.

units. Direct current may be supplied by batteries or by an a.c.-d.c. converter.

Refrigeration in the laboratory consists of a deep-freeze unit, a 150-cubic foot reefer box, and electric household-type refrigerators.

Small stocks of routine glassware and reagents are maintained at the laboratory. Certain equipment such as *p*H meters, colorimeters, Warburg-Barcroft apparatus, Van-Slyke apparatus, cathode ray oscilloscope, and other physiological equipment, microscopes, microtomes, balances, cameras, and virtually any other needed item will be supplied by the University from its main campus when the need for them arises. All investigators, however, are requested to submit a detailed list of their needs so that they may be advised of what the Laboratory is in a position to supply.

Field equipment: The opportunities for investigators to conduct research in the field and to observe marine species in their natural environment constitute one of the chief attractions of the Laboratory, and every effort is made to assist investigators on projects requiring this type of approach.

The field equipment includes the 46-foot research vessel, the *Salpa* (Fig. 6), which has a live well with circulating sea water and hoisting gear for dredging, hauling plankton nets, and hydrographic work. Gear such as dredges, seines, and nets of various sorts, traps, plankton nets from small to meter-size openings, Clarke-Bumpus and high-speed quantitative plankton nets, current meters, Nansen bottles with reversing thermometers, bathythermographs, glass-bottom boxes, and diving equipment is available. As with laboratory supplies, investigators are advised to inquire in advance as to their particular requirements.

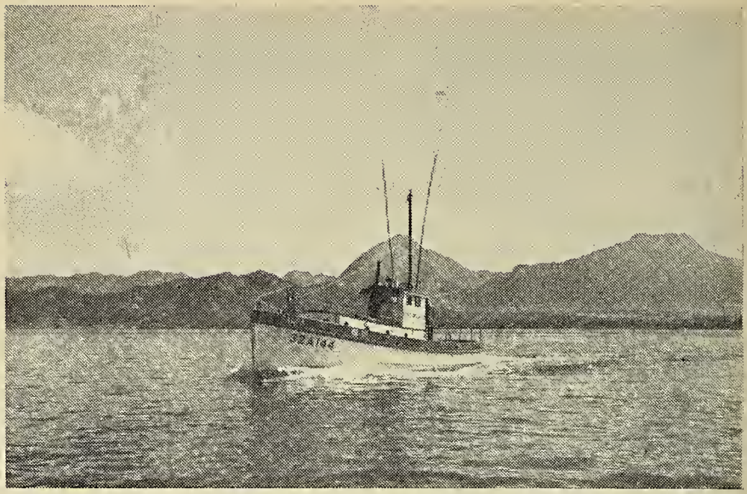

FIG. 6. The *Salpa*.

In cooperation with the Territorial Division of Fish and Game and the Pacific Oceanic Fishery Investigations, larger vessels for work at sea and for deeper dredging are often available to qualified investigators. Such cooperation must be arranged for well in advance.

Library facilities and publications: The proximity of the extensive libraries of the University of Hawaii, Bernice P. Bishop Museum, Hawaiian Sugar Planters' Association Experiment Station, Pineapple Research Institute, and the Pacific Oceanic Fishery Investigations make it unnecessary to maintain a separate library at the Laboratory. At these libraries investigators may secure reference material needed for use at Coconut Island. Microfilm readers are available at the University Library.

The Hawaii Marine Laboratory issues two series of publications. The "Contributions from the Hawaii Marine Laboratory" are technical papers published in suitable journals and are numbered serially. Papers in this series are available to individuals in the fields of their interest, and to institutions which may request individual or all papers of the series. Exchanges are desired. A second series of mimeographed leaflets, entitled "Hawaii

Marine Laboratory News Circular," is sent to interested persons or institutions.

Housing: Housing for four couples and about ten single investigators is available at the Coconut Island residential area. Since all investigators automatically become temporary (although unpaid) members of the staff of the University, other apartments and houses are frequently available on the main campus. These would be more suitable for investigators with families. The rental fee is nominal, and arrangements should be made several weeks or months in advance. Community kitchen and dining room facilities are available at the Laboratory.

Staff: An advisory board deals with general policies and the distribution of working space if the demand exceeds that available. The Board members are Dr. Albert W. Bellamy, Professor of Zoology, University of California at Los Angeles; Mr. Vernon E. Brock, Director, Territorial Division of Fish and Game; Dr. Robert W. Hiatt, Chairman of the Board and Director of the Laboratory, Professor of Zoology, University of Hawaii; Dr. Carl L. Hubbs, Professor of Zoology, Scripps Institution of Oceanography of the University of California; Dr. George F. Papenfuss, Associate Professor of Botany, University of California; and Dr. Albert L. Tester, Professor of Zoology, University of Hawaii.

The resident research staff includes Dr. Albert H. Banner, Associate Professor of Zoology (biological oceanography); Mr. Vernon E. Brock, Lecturer in Fishery Biology (ichthyology, fishery biology); Dr. George W. Chu, Associate Professor of Zoology (parasitology); Dr. Maxwell S. Doty, Associate Professor of Botany (marine botany); Dr. William A. Gosline, Associate Professor of Zoology (ichthyology); Dr. Robert W. Hiatt, Professor of Zoology (marine invertebrates, ecology); Dr. Sidney C. Hsiao, Associate Professor of Zoology (experimental embryology, physiology); Dr. John L. Kask, Lecturer in Fishery Biology (fishery biology); Dr. Donald C. Matthews, Associate Professor of Zoology (invertebrate zoology); Mr. O. E. Sette, Lecturer in Fishery Biology (fishery biology); Dr. Albert L. Tester, Professor of Zoology (fishery biology, biometrics); and Dr. Pieter van Weel, Professor of Zoology (comparative physiology).

The Osteology and Classification of the Ophichthid Eels of the Hawaiian Islands[1]

William A. Gosline[2]

INTRODUCTION

The classification of the eels of the family Ophichthidae is, as Myers and Storey (1939: 156) put it, in the utmost confusion. Their suggested solution, with which I heartily concur, is a sound anatomical study of all the included genera. This cannot be undertaken in the present paper as the family is of circumtropical distribution and many of the genera are unavailable to me. Nevertheless, a rather large and representative group of these eels is present in the Hawaiian Islands. The osteology of the most divergent of these has been investigated in the hope of providing at least a basis for work on ophichthid relationships. The results of this study and of two others already completed (Gosline, 1950, and in press) have borne out the necessity for the entire realignment of the Ophichthidae which Myers and Storey (1939: 157) predicted.

The taxonomic section of this paper deals with all species of ophichthid eels recorded from the Hawaiian Islands (including Johnston Island). One new genus, one new subgenus, and two new species are described, and a substitute specific name is proposed. These are as follows.

Genus: *Phyllophichthus*
Subgenus: *Schultzidia*
Species: *Phyllophichthus xenodontus*
Caecula (*Sphagebranchus*) *platyrhyncha*
Myrichthys bleekeri (to replace *M. semicinctus*)

The paper is concluded with a brief discussion of the distribution of Hawaiian ophichthids.

However, before dealing with these matters, the use of the name Ophichthidae for this family needs explanation. The genus *Ophichthus* (Thunberg and Ahl, 1789: 5) was corrected by nineteenth-century classicists to *Ophichthys*, and the family was called Ophichthyidae. In recent years ichthyologists have returned to the original spelling of the generic name but have retained the emended form of family name. This is illogical and nomenclatorially incorrect. A more serious difficulty arises from the fact that the first family name proposed for the group is Ophisuridae (M'Clelland, 1844: 211). However, whether or not *Ophisurus* is a valid genus is a moot nomenclatorial question. Consequently I prefer not to use for this family, at the present time, the little-known and possibly invalid name Ophisuridae.

Acknowledgments: I wish to acknowledge assistance received from several persons. To the staff of the Pacific Oceanic Fishery Investigations I am indebted for the use of their X-ray equipment and for permission to go to sea on the fishery research ship "Hugh M. Smith." To my shipmates aboard this vessel I am under obligation for help in collecting fishes at various points in the Hawaiian and Phoenix Islands. I am grateful to Dr. C. H. Edmondson and Mr. C. J. Lathrop for permission to examine the ophichthids in the Bishop Museum. Mr. J. Böhlke has kindly looked up literature regarding the name *Ophisurus*. The duplicate series of fishes from Bikini sent me by Dr. L. P. Schultz has been used for comparative purposes. Dr. E. J. Britten has made photomicrographs of the tails of two specimens for me, and Mr. E. L. Gillespie has shaded several of my illustrations.

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[1] Contribution No. 6, Hawaii Marine Laboratory.

[2] Department of Zoology, University of Hawaii. Manuscript received September 29, 1950.

OSTEOLOGY

The most diverse of the Hawaiian ophichthids were selected for osteological study. In general the heads, branchial arches, and pectoral girdles were stained with alizarin and dissected; in *Brachysomophis henshawi* the right side of the head of the only available specimen (and apparently the third known) was dissected without staining. The bodies of the fishes studied were X-rayed, though some specimens were stained and rather unsuccessfully cleared. The species studied in this manner were as follows:

Subfamily MYROPHINAE

Muraenichthys (*Muraenichthys*) *cookei* (Figs. 3, 10*a*, 12*b*, 13).

Subfamily OPHICHTHINAE

Caecula (*Sphagebranchus*) *platyrhyncha* (Figs. 1, 14*b*,*d*).
Myrichthys maculosus (Figs. 5, 7–9, 15*b*).
Cirrhimuraena macgregori (Figs. 6, 10*b*, 16).
Leiuranus semicinctus (Figs. 4, 17*c*).
Brachysomophis henshawi (Figs. 2, 18).

LATERAL LINE SYSTEM OF HEAD AND ASSOCIATED BONES. The pattern of the lateral line system of the head in the Ophichthidae has already been described in considerable detail for "*Ophichthys serpens*" by Allis (1903: 126) and is illustrated here in Figures 1 and 15. It is quite uniform in the species studied.

On the other hand, the degree of development of many of the bones through which the canals pass varies considerably. The canals are enclosed in a series of bony ossicles except where they penetrate the pterotics, frontals, and dentary. These ossicles may be small, separate, bony cylinders; they may be united into more or less elongate tubes; or such a tube may be expanded into a bone of considerable extent. In *Brachysomophis* the ossification of the lateral line system is the most complete (Fig. 2*a*). In that genus the nasal as usual is well developed; in addition the postorbitals form a strong strut for the support of the maxillary, the suborbitals form a tube closely appressed against the maxillary, the preopercle is laminated, and a small

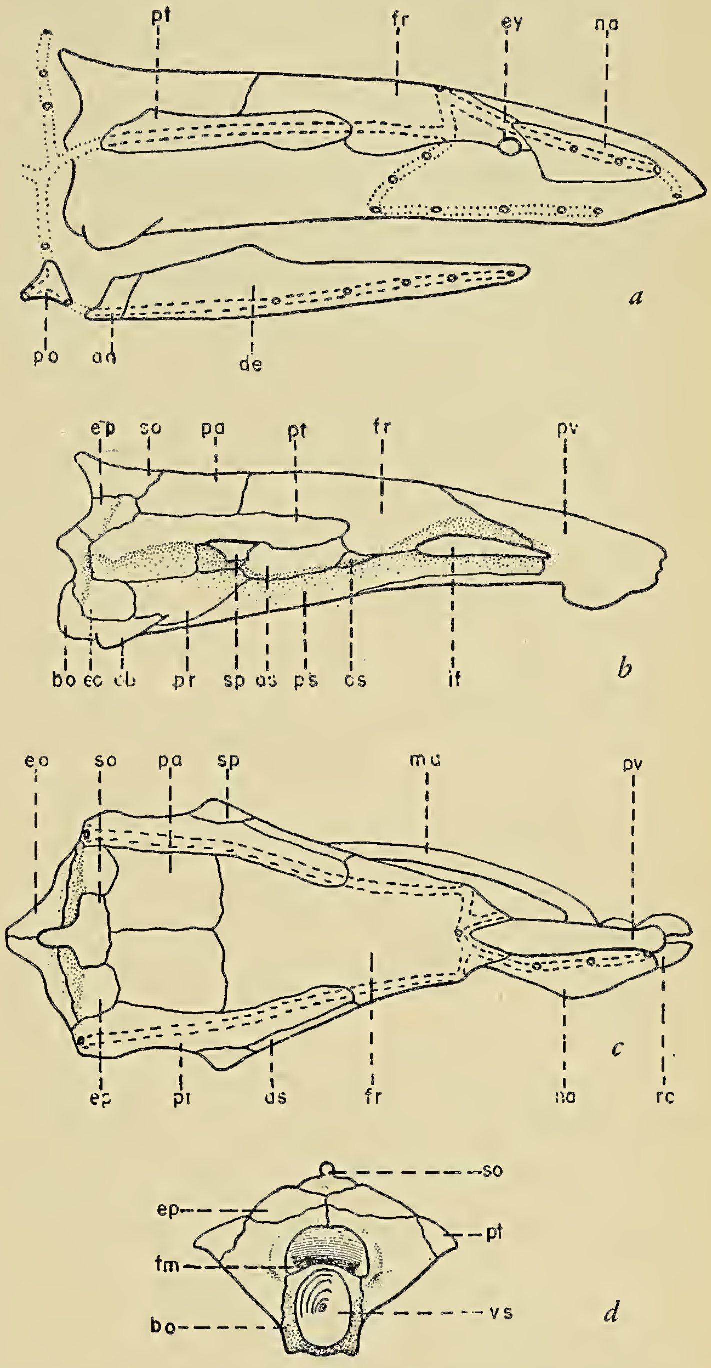

Fig. 1. *Caecula* (*Sphagebranchus*) *platyrhyncha*. *a*, Right side of head, showing lateral line canals and pores. Canals passing through bony ossicles dotted; canals passing through head bones dashed and the outlines of such bones indicated. aa, Articular-angular; de, dentary; ey, eye; fr, frontal; na, nasal; po, preopercle; pt, pterotic. *b*, Right side of cranium. Teeth omitted in this and most of the following figures. as, Alisphenoid; bo, basioccipital; eo, exoccipital; ep, epiotic; fr, frontal; if, interorbital opening; ob, otic bulla; os, orbitosphenoid; pa, parietal; pr, prootic; ps, parasphenoid; pt, pterotic; pv, premaxillary-ethmovomer; so, supraoccipital; sp, sphenotic. *c*, Cranium from above. Lateral line canals of cranial bones drawn in. The nasal (na) is included on the right side, the maxillary (ma) on the left, and the rostral cartilages (rc) in front. Other labels as in Fig. 1*b*. *d*, Skull from rear. Bones labeled as in Fig. 1*b*. fm, Foramen magnum; vs, socket for centrum of first vertebra.

lacrymal appears to be developed. In other genera examined the circumorbitals are reduced to a series of ossicles enclosing the infraorbital canal, and the preopercle is usually almost rudimentary.

OPERCULAR APPARATUS. The opercular apparatus shows various degrees of reduction in the ophichthids examined. In general, the body of the operculum lies mostly or entirely below its articular facet, though it projects upward to a considerable extent in *Brachysomophis* (Fig. 2*a*) and, to some extent, in *Caecula*. The suboperculum and interoperculum are wedge-shaped bones, but in *Muraenichthys* the suboperculum (Fig. 3*a*) sends out a backward projection that encloses the lower edge of the operculum. The preoperculum is moderately developed in *Brachysomophis*, *Leiuranus*, and *Cirrhimuraena*, or is reduced to a tube for the lateral line canal in *Muraenichthys* and *Caecula*. In general, it may be said that the opercular system of *Brachysomophis* is the least, and that of *Muraenichthys* the most, specialized (or degenerate).

SUSPENSORIUM. The suspensorium of *Muraenichthys* (Fig. 3*a*) differs from that of the other species examined in being somewhat forwardly inclined. In all, the palatopterygoid is a laminar bone more or less loosely attached to the hyomandibular and quadrate posteriorly, and by ligament to the maxillary laterally and the skull mesially.

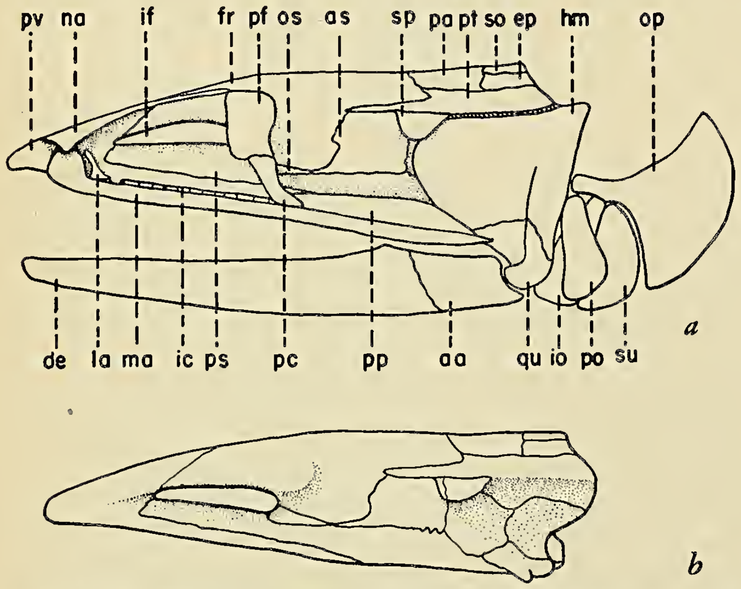

FIG. 2. *Brachysomophis henshawi*. *a*, Bones of left side of head. hm, Hyomandibular; ic, infraorbital canal; io, interopercle; la, lacrymal?; ma, maxillary; op, opercle; pc, enlarged postorbital ossicle; pf, postfrontal; po, preopercle; pp, palatopterygoid; qu, quadrate; su, subopercle. Other labels as in Fig. 1*b*. *b*, Skull from left. Bones as in Fig. 1*c*.

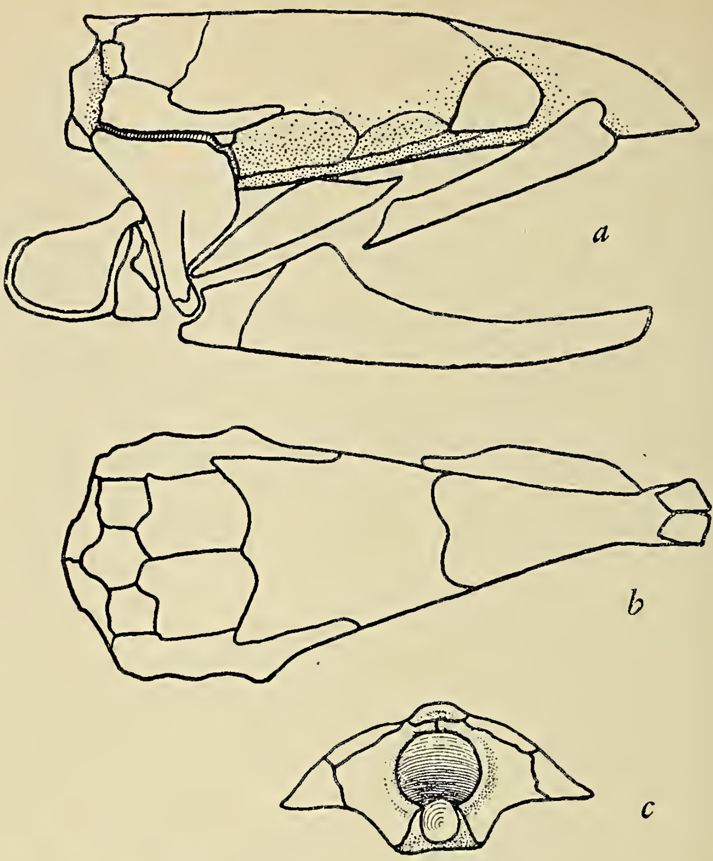

FIG. 3. *Muraenichthys* (*Muraenichthys*) *cookei*. *a*, Head bones from right. Bones as in Fig. 2*a*. *b*, Skull from above. Nasal included on left side. Bones as in Fig. 1*c*. *c*, Skull from rear. Bones as in Fig. 1*d*.

LOWER JAW. The lower jaw is inferior to the upper except in *Brachysomophis* (Fig. 2*a*) where it projects and, like the upper, bears large, sharp canine teeth.

MAXILLARIES. The maxillaries articulate at a more or less variable distance from the tip of the rostrum, far forward in *Brachysomophis* (Fig. 2*a*), more posteriorly in the others. Usually the dentigerous part of the maxillaries terminates well forward of the highest part of the dentary, though an ossified ligament may extend farther back. In *Brachysomophis*, however, the maxillary is a long, toothed bone extending back almost to the level of the lower jaw articulation; it is supported above, as already noted, by the postorbitals.

Another type of jaw specialization is found in *Leiuranus.* Here the two maxillaries have moved toward each other across the roof of the mouth until their forward ends abut against one another (Fig. 4*b*).

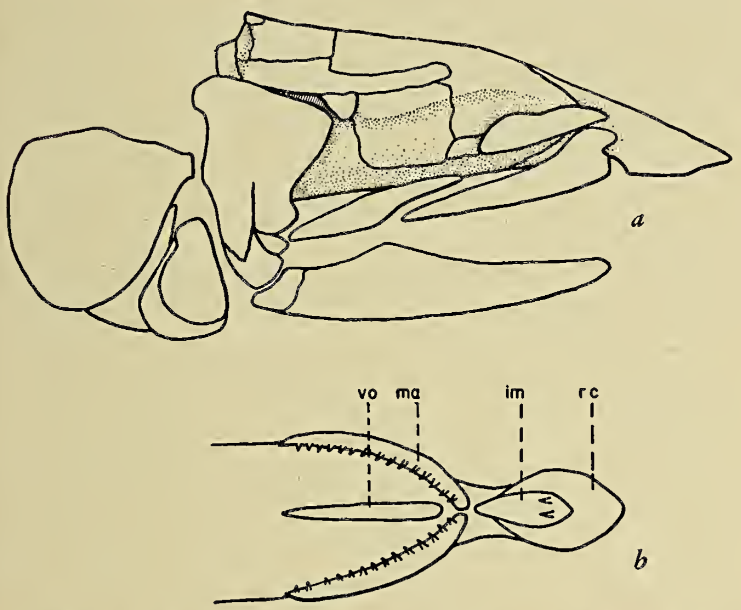

FIG. 4. *Leiuranus semicinctus. a,* Head bones from right. Bones as in Fig. 2*b*. *b,* Bones of roof of mouth from below, semidiagrammatic. Teeth indicated. im, Intermaxillary area of premaxillary-ethmo-vomer; ma. maxillary; rc, rostral cartilage; vo, vomerine area of premaxillary-ethmo-vomer.

SKULL. In the cranium of the species examined the greatest difference is between *Myrichthys* and the others. In *Myrichthys* (Fig. 5) the snout is blunt and rounded and the skull is short and high. The interorbital opening seems to have been compressed from front to rear and is elongate vertically. The orbitosphenoids are large, apparently filling that part of the skull wall left by the withdrawal upward of the frontals. In the other genera the interorbital opening is always longer than high. In those species with especially long, low skulls, e. g., *Caecula platyrhyncha* and *Brachysomophis henshawi*, the opening is almost slitlike, whereas in those with a moderately high skull, e. g., *Muraenichthys cookei* and *Cirrhimuraena macgregori*, it is more rounded. In all but *Myrichthys* the orbitosphenoid appears to be more or less squeezed out externally by the frontals above and the parasphenoid below.

In most of the Ophichthidae the ethmoid projects up over the dorsal surface of the frontals as a subtriangular median wedge (Fig. 1*c*). However, in *Myrichthys* (Fig. 5*b*) and *Muraenichthys* (Fig. 3*b*) the projection is broad and bilobed.

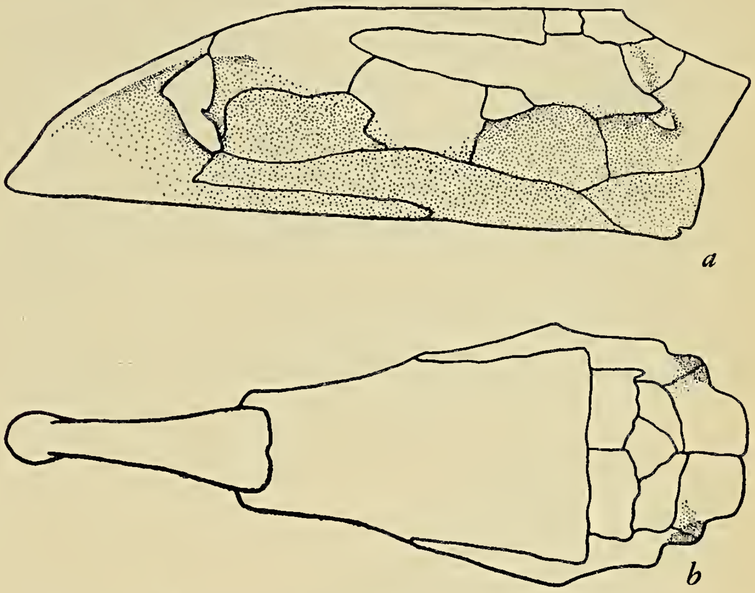

FIG. 5. *Myrichthys maculosus. a,* Cranium from left; *b,* from above. Bones as in Fig. 1.

In all the ophichthids examined, auditory bullae are developed as bulges on the ventral surface of the skull. These bullae are formed from parts of the basioccipitals, exoccipitals, and prootics. Axial muscles from the body attach especially to the basioccipitals which, in *Brachysomophis*, form a distinct lobe for this purpose (Fig. 2*b*). Auditory bullae are least prominent in *Cirrhimuraena* (Fig. 6*b*).

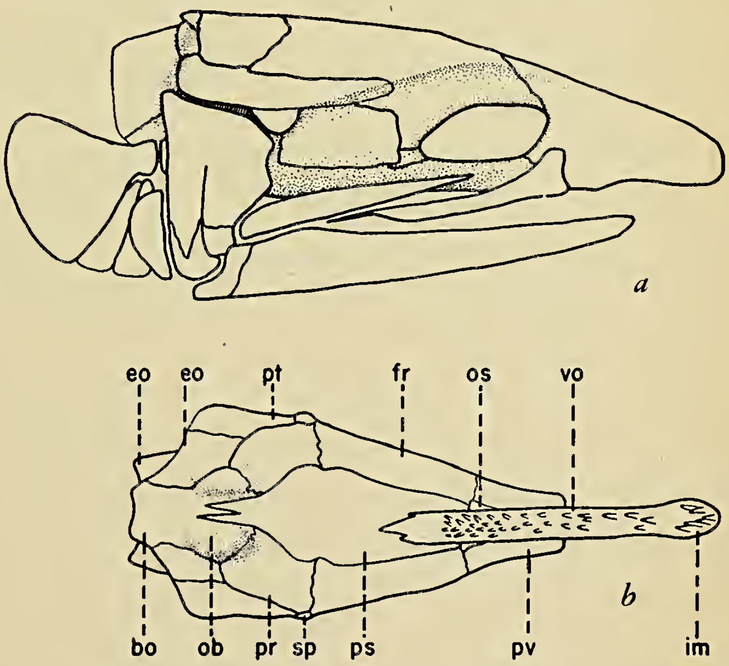

FIG. 6. *Cirrhimuraena macgregori. a,* Head bones from right. Bones as in Fig. 2*a*. *b,* Skull from below. Teeth shown. Labels as in Figs. 1*b* and 4*b*.

The skulls of the six genera examined also vary in the distance they project behind the supraoccipital. In *Brachysomophis* the skull is relatively truncate behind; in *Myrichthys*, at the other extreme (Fig. 5), a rather large section of the skull lies behind the supraoccipital.

GILL ARCHES. The gill arches of species of *Muraenichthys*, *Leiuranus*, *Ophichthus*, *Pisoodonophis* ("*Ophichthys boro*"), and *Myrichthys* ("*Ophichthys colubrinus*") have been briefly dealt with by Popta (1906). The gill arches of *Myrichthys maculosus* are illustrated in Figure 7.

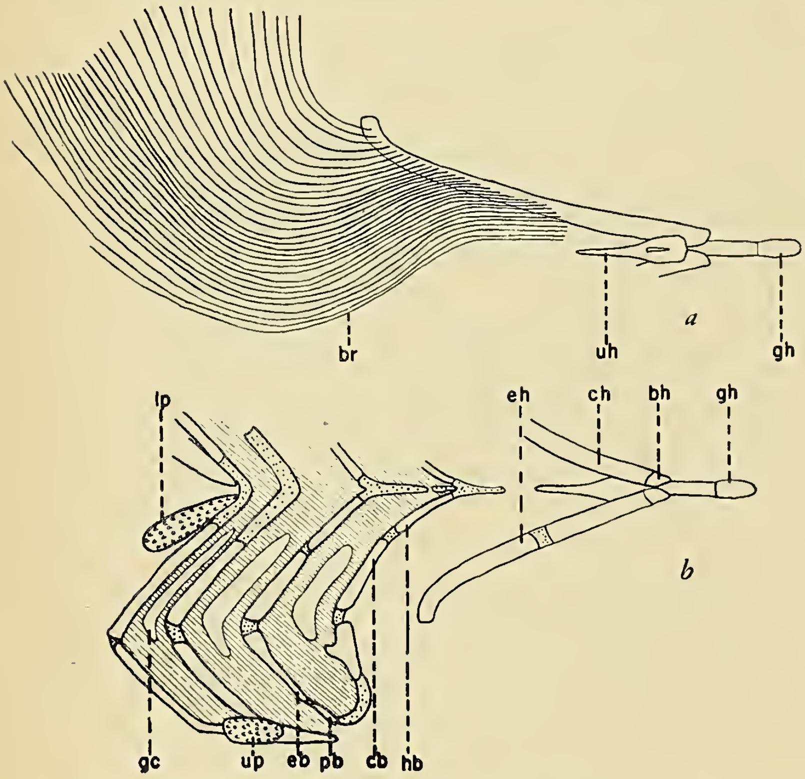

FIG. 7. *Myrichthys maculosus*. *a*, Outline of right side of hyoid apparatus from below. br, Branchiostegal ray; gl, glossohyal; uh, urohyal. *b*, Right gill arches from above, the upper parts opened out. Branchiostegal rays not shown. Cartilage areas stippled. bh, Basihyal; cb, ceratobranchial; ch, ceratohyal; eb, epibranchial; eh, epihyal; gc, gill cleft; gh, glossohyal; hb, hypobranchial; lp, lower pharyngeal; pb, pharyngobranchial; up, upper pharyngeal.

Within the forms examined, the number of branchiostegal rays on one side are as follows: *Caecula platyrhyncha*, 17; *Brachysomophis*, 18; *Cirrhimuraena*, 24; *Muraenichthys cookei*, 26; *Leiuranus*, 28; and *Myrichthys maculosus*, 32. In all of these the branchiostegal rays of the two sides of the head overlap broadly on the midventral line.

The pharyngeal teeth in all of these forms except *Myrichthys* are small, sharp, and depressible; in *Myrichthys* they are blunt and little movable. In all, the upper pharyngeals are shorter and broader than the lower, most notably so in *Brachysomophis*. In *Muraenichthys*, *Leiuranus*, and *Brachysomophis* the lower pharyngeals are elongate and biserial; in the other three genera they are club-shaped to ovate. The number of teeth on a pharyngeal varies from 18 to 34 in the different forms.

PECTORAL GIRDLE. The pectoral girdle seems always to be represented. Judging from X rays it is reduced to a cleithrum and possibly a supracleithrum in *Caecula*. In *Myrichthys* a rudimentary bone which is probably the coracoid (Fig. 8) is embedded in a cartilaginous plate. In *Cirrhimuraena*, scapula, coracoid, and a single actinost are present as well as cleithrum and supracleithrum.

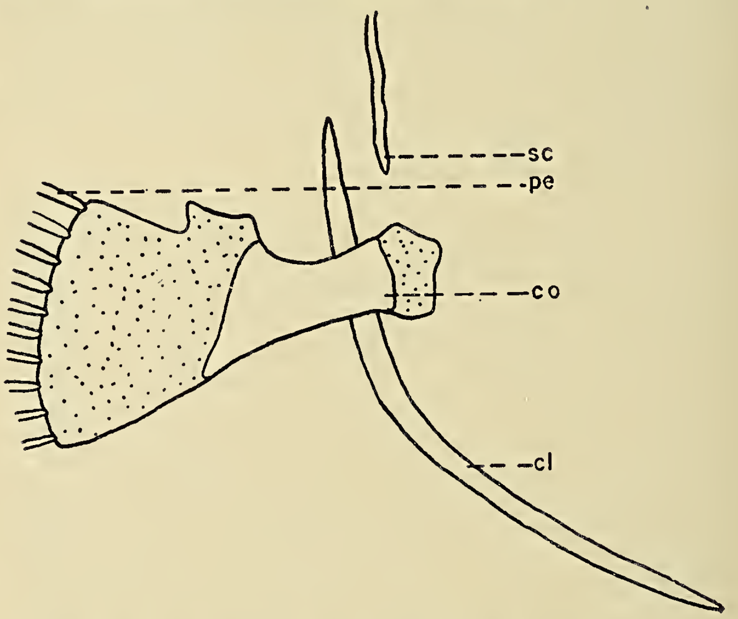

FIG. 8. *Myrichthys maculosus*. Left half of pectoral girdle from inside. Cartilage areas stippled. cl, Cleithrum; co, coracoid?; pe, base of pectoral ray; sc, supracleithrum.

AXIAL SKELETON. Inasmuch as the nature of the vertebral column cannot be properly illustrated in its entirety, and as it has been used as a basis of family definition by Regan (1912: 386), it must be described in a general way. The following account is based primarily on *Myrichthys*, *Brachysomophis*, and *Caecula*. The first centrum is not fused to the skull; it is short, and its neural arch extends backward over the centrum of the second vertebra (Fig. 9*a*). At about the sixth vertebra the centra develop, ventrally, broad lateral flanges that continue to the anus (Figs. 9*b*,*c*). These are replaced in the caudal vertebrae by strong transverse processes above the haemal arches (Fig. 9*d*). Neural spines are undeveloped except often as small backward projections from a few anterior vertebrae. Epineurals and epipleurals are developed in each anterior segment starting from the anterior part of the column or basioccipital (Fig. 9*a–d*). Pleural ribs are present along most of the column and may be distinctly laminate (Fig. 9*b*,*c*). Epipleurals, epineurals, and pleural ribs extend outward and backward for most of the length of the fish. However, in the tail region these structures are replaced by a series of intermuscular bones, four to each vertebra, extending outward and forward (Fig. 10*b*). *Muraenichthys* lacks such intermuscular bones. Otherwise, the vertebral column in the species studied appears to be rather uniform.

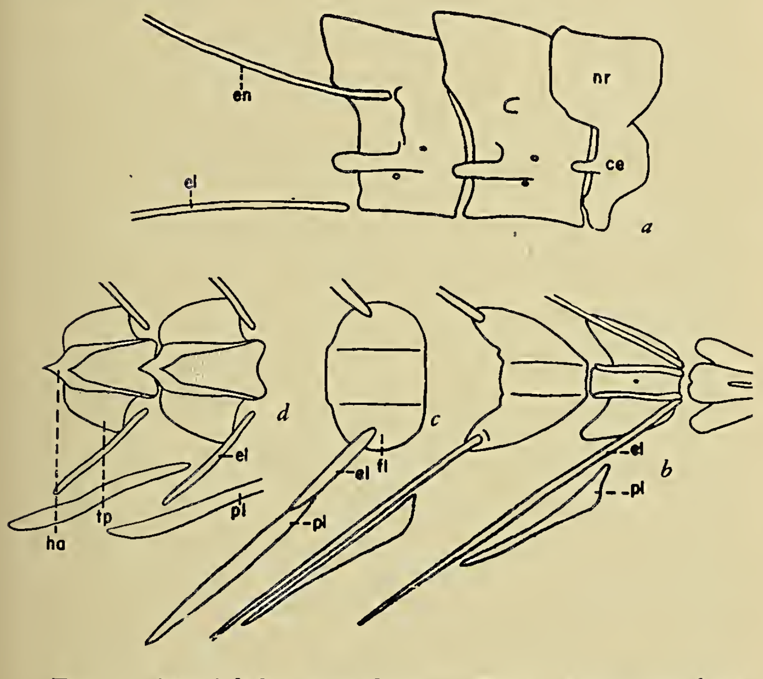

FIG. 9. *Myrichthys maculosus*. *a*, First three vertebrae from right. Epineurals and epipleurals are omitted from first two. ce, Centrum; el, epipleural; en, epineural; nr, neural arch. *b*, Vertebrae 4–6; *c*, vertebra 26; *d*, two anterior caudal vertebrae from below. el, Epipleural; fl, lateral flange of centrum; ha, haemal arch; pl, pleural rib; tp, transverse process of centrum.

The total numbers of vertebrae for several ophichthids are shown in Table 1. Lateral-line pore counts for the body were also made (Table 1) in the hope that these might prove indicators of vertebral number. In a general way, such is the case. The discrepancies between pore counts for the body and the number of vertebrae is probably due, at least in part, to the fact that lateral line pores stop short of the tip of the tail, notably so in *Brachysomophis*. For example, in *Cirrhimuraena macgregori*, with a vertebral count of 181 and with 172 pores, the last pore is over the 171st vertebra.

TABLE 1

VERTEBRAL NUMBERS AND PORE COUNTS IN CERTAIN OPHICHTHIDS

SPECIES	NUMBER OF VERTEBRAE	PORES IN LATERAL LINE
Caecula platyrhyncha	120	120
Brachysomophis henshawi	130	111
Muraenichthys cookei	130	122
Caecula flavicauda	153	153
Leiuranus semicinctus	168	158
Machaerenchelys phoenixensis	169	163
Phyllophichthus xenodontus	170	160
Myrichthys maculosus	178	162
Cirrhimuraena macgregori	181	172
Callechelys luteus	213	208

TAIL. In the past *Muraenichthys* has been placed in a different family from the other genera studied here. The sole reason for this is that *Muraenichthys* has a rudimentary fin around the tip of the tail, whereas the others have the tail protruding as a fleshy point. Osteologically, the difference between the tails of *Muraenichthys* (Fig. 10*a*) and *Cirrhimuraena* (Fig. 10*b*) is less than that between those of *Cirrhimuraena* and *Caecula platyrhyncha*. Rudimentary rays are present around the tails of both *Muraenichthys* and *Cirrhimuraena*; they are merely embedded in flesh in *Cirrhimuraena* (as also in *Myrichthys*). In *Caecula platyrhyncha*, on the other hand, there are no rudimentary rays either around the tip of the tail or elsewhere. It is obvious from this discussion and more obvious from Figure 10 that a separate family cannot be maintained for *Muraenichthys* on the basis of tail structure.

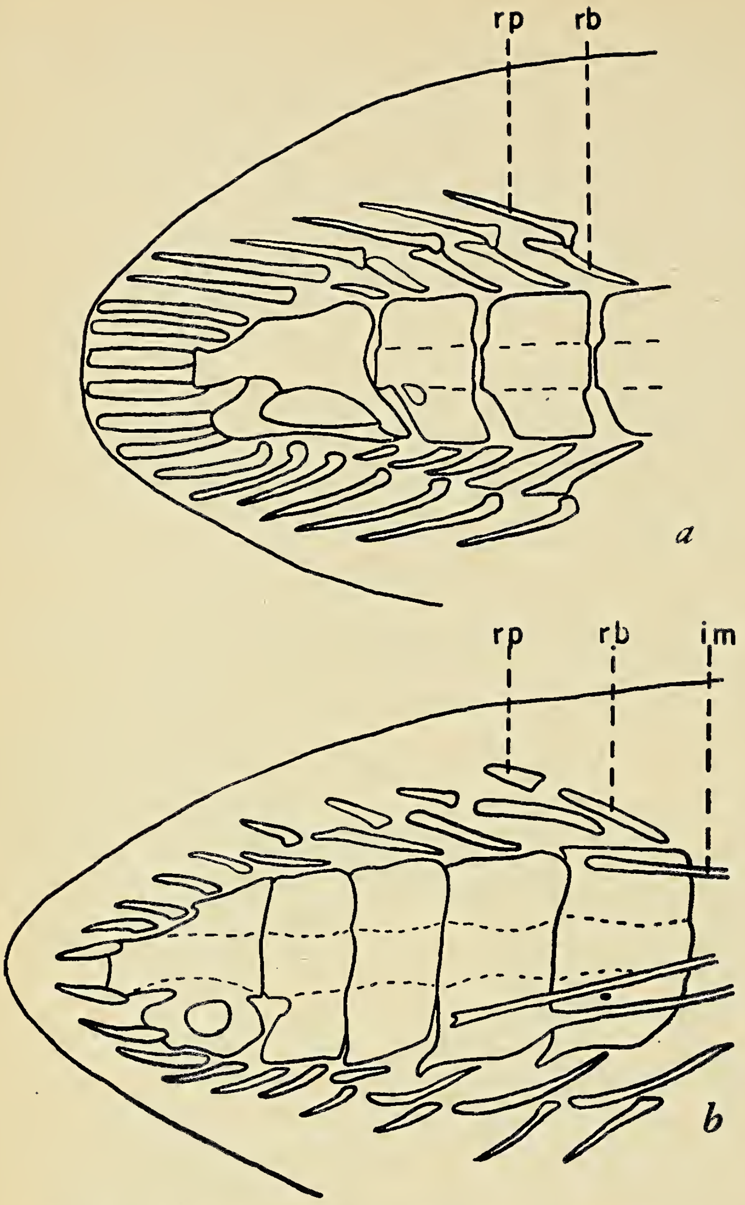

FIG. 10. *a*, Tail of *Muraenichthys* (*Muraenichthys*) *cookei;* b, of *Cirrhimuraena macgregori.* im, Intermuscular bone; rb, basal segment of fin ray; rp, peripheral segment of fin ray.

DIAGNOSIS AND RELATIONSHIPS

Compared with other eel families the most diagnostic features of the Ophichthidae appear to be as follows:

> Dorsal and anal rays either reduced or absent at tip of tail. Posterior nostril below the level of the eye, either on the inside or the outside of the upper lip. Skull not truncate behind. Frontals fused to form a single bone. Suspensorium nearly or quite vertical. Auditory bullae present. Branchiostegal rays of the two sides of the head broadly overlapping on the mid-ventral line. Neural spines rudimentary. Intermuscular bones well developed. Strong transverse processes on caudal vertebrae.

Since the appearance of Regan's excellent paper on eel classification (1912), it has been generally agreed that the Ophichthidae are a specialized offshoot of the congrid stock. Nevertheless, it is necessary here to compare the ophichthids and congrids, partly because no adequate comparison of the two groups exists, and partly to indicate the nature of the specializations in the Ophichthidae.

The ophichthids differ immediately in two superficial characters—the labial nostril and the reduced or absent tail fin. However, these characters are not as significant as they might appear to be.

In the Congridae the posterior nostril opens out in the cheek in front of the eye. A posterolateral deflection of this opening would place it where it occurs in the ophichthid *Caecula flavicauda* (Fig. 14*a*). In those ophichthids that have the narial opening inside the upper lip, the posterior nostril is carried down in a tube (outside the infraorbital canal, as pointed out by Allis [1903]) over the surface of the upper lip and into the mouth. Often the groove behind this tube is still visible externally, as in *Myrichthys* (Fig. 15), but sometimes the tube has been completely fused into the lip. This same specilization of an internal posterior nostril occurs in the unrelated family provisionally called Echelidae (Gosline, 1950).

The reduction or loss of fin rays at the tip of the tail is probably an adaptation to digging, as pointed out by Myers and Storey (1939: 157). That such loss is secondary is shown by the presence of reduced fin rays around the tail of Myrophinae (Fig. 10*a*) and the fin rudiments that remain in certain Ophichthinae (Fig. 10*b*).

Osteologically, *Conger* (Fig. 11) shows numerous characters in which it is undoubtedly more primitive than the Ophichthidae. In most of these it resembles the Anguillidae. However, the Congridae and the Anguillidae differ at once in that the frontals of the Anguillidae are separate, whereas those of the Congridae are fused into a single bone. Pri-

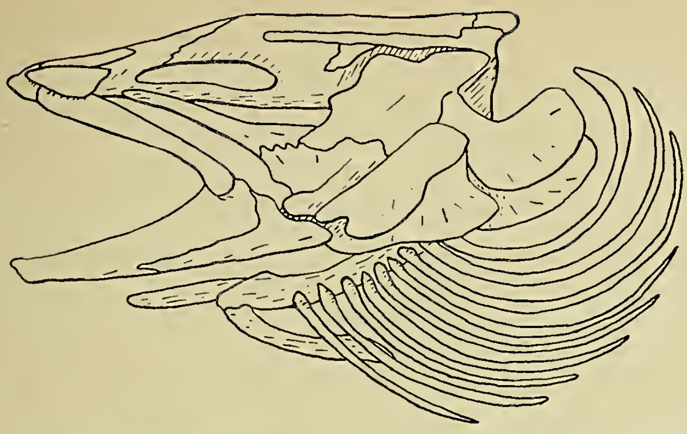

FIG. 11. Head bones of *Conger vulgaris*, after Goodrich.

marily because of this difference, Regan (1912) has, by implication, postulated these two families as being near the starting points of the two main lines of eel evolution. The ophichthids belong in the congrid line.

In *Conger* the suspensorium is well developed and its bones are well integrated, i. e., the palatopterygoid is united by suture with both the quadrate and the hyomandibular. The opercular bones are all large and well developed for eels. The branchiostegals are few (9–9), and those of the two sides do not overlap on the mid-line. The large basihyal projects into the free tongue. These are all primitive characters as compared with the Ophichthidae. *Conger* and *Anguilla* agree in having the skull long and low (this does not seem to me to be a necessarily primitive feature) and in certain associated bone arrangements, i. e., the interorbital opening, alisphenoids, and pterotics are longitudinally elongate, and the orbitosphenoid is small or absent externally. Unlike most ophichthids, but like *Anguilla*, *Conger* has the suspensorium forwardly inclined, and has the intermaxillary and vomerine teeth in an almost continuous series. Unlike most eels that I have examined, including the ophichthids, *Conger* lacks the cross commissure of the lateral line system in the frontals that gives rise to a middorsal pore.

The head skeleton of the Ophichthidae differs from that of *Conger* in four principal ways: (1) there has been a further reduction in the size and strength of certain of the skull bones; (2) the suspensorium has become nearly or quite vertical; (3) the branchiostegal rays have developed a basketlike arrangement on the throat; and (4) an auditory bulla is present.

The bones that have undergone further reduction are the palatopterygoid, the elements of the opercular series, and the preorbital.

It is impossible to say, but seems probable, that the change from a forwardly inclined suspensorium in *Conger* to the nearly vertical one of the Ophichthidae is functionally related to the inferior mouth of most ophichthids. At any rate, in *Conger* much of the adductor muscle of the mandible runs upward and backward to attach to an aponeurosis on the posterodorsal angle of the skull. In the Ophichthidae (with a vertical suspensorium and a more posterior articulation of the mandible) the adductor muscles run more directly up over the skull, and the posterodorsal crest of *Conger* is reduced or totally absent. In addition, the opercular musculature, which attaches to the rear of this same crest in *Conger*, is much reduced in the Ophichthidae. Thus, the skull of the ophichthids, instead of ending posteriorly in an acute edge, usually tapers off more or less gradually into the vertebral column.

Certain other changes in the head skeleton appear to be related to the backward displacement of the quadrate in ophichthids. The maxillary, the posterior end of which abuts against the dentary in *Conger*, usually falls far short of this bone in ophichthids and, except in *Brachysomophis*, is attached to the mandible only by a long, slender, and sometimes ossified ligament. Also, in ophichthids, the palatopterygoid has lost its importance as a strut between the suspensorium and the skull, and has become more or less reduced and disarticulated.

In *Conger*, with forwardly suspended jaw and moderately well-developed opercular apparatus, the gill arches lie largely below the skull, and the gill openings are less than a skull length behind. In ophichthids, on the other hand, the gill arches lie mostly behind the skull, and the gill openings are more than a skull length from its posterior border. The peculiar basketlike arrangement of the branchiostegal rays has doubtless been developed in ophichthids to shield this otherwise unsupported area of the gill arches. It seems anomalous that a similar arrangement has not been developed in other eel families with posteriorly placed gill arches.

The auditory bulla, though variable in the Ophichthidae, is always present. No trace of this structure is visible externally in the skull of *Conger*.

The pectoral girdle is less degenerate (hence more primitive) in *Conger*, which retains four actinosts, than in ophichthids, in which one actinost at most has been found and in which the girdle may be reduced to a cleithrum and supracleithrum.

Regan's chief osteological differentiation (1912) between the Congridae and Ophichthidae lay in the vestigial neural spines of the latter family. In addition, the intermuscular bones of ophichthids are well developed, and the pleural ribs are often laminar.

From this comparison it is plain that the Ophichthidae and *Conger* are very well separated. If other genera of the Congridae or other eel families are more closely related to the Ophichthidae, there is nothing in the literature to indicate it.

Within the Ophichthidae several minor lines of evolutionary development seem to be represented. It seems justified on zoological grounds (as well as from precedent) to remove *Muraenichthys*, subfamily Myrophinae, first (Gosline, 1950). This genus has two primitive features not found in the other genera examined: the dorsal and anal form an externally visible fin around the tip of the tail, and, in *M. cookei* at least, the suspensorium is somewhat forwardly directed. *M. cookei* also has a moderately short skull with roundish interorbital opening, and the ethmoid projects over the frontals as a rather broad, bilobed plate. In these two features *Muraenichthys* disagrees with *Conger* and with all but *Myrichthys* of the Ophichthidae examined.

Within the subfamily Ophichthinae, one specialized group contains *Brachysomophis* and probably also *Ophisurus* (or *Oxystomus*). These two genera have developed, probably *via Ophichthus*, a protruding lower jaw, fanglike teeth, and an extremely long maxillary supported (as in some muraenids) by a strut of postorbital ossicles. These characters are probably all functional adaptations for fish-eating. In other respects (as well as in the low vertebral number) the skull of *Brachysomophis* resembles that of the weak-jawed *Caecula*.

Another group that can immediately be separated from other Ophichthinae contains *Myrichthys* and probably *Callechelys*. *Myrichthys* (Fig. 5) has a relatively short, high skull, vertically elongate interorbital opening, large orbitosphenoid, and broad, emarginate posterodorsal ethmoid projection. In these characters *Myrichthys* resembles *Muraenichthys*, though convergent evolution rather than close relationship would seem indicated. At any rate, *Myrichthys* and *Callechelys* differ from *Muraenichthys* and most other ophicth," thids in the large number of vertebrae and in having the relatively high dorsal commencing far forward on the head.

The remaining genera studied are all rather similar internally, though a *Machaerenchelys-Leiuranus-Phyllophichthus* group can be easily separated on tooth characters. In these three genera the vomerine teeth are few or absent and are replaced functionally by those of the maxillaries which have moved in toward the center of the upper jaw.

The last three genera to be dealt with are *Caecula*, *Cirrhimuraena*, and *Ophichthus*. Probably these are not closely interrelated, but I cannot place them with other generic groups. *Caecula* itself may be composite, as it is characterized merely by having the fins rudimentary or absent. (Jordan and Evermann [1896: 374] state, on what basis I do not know, that *Sphagebranchus* [= *Caecula*] "is the most simple in structure among the

Ophichthyidae [=Ophichthinae], as *Ophichthus* is probably the most specialized.") *Cirrhimuraena*, except for the fringed lip, seems to be a rather generalized type of ophichthid, possessing, among other things, a better-developed pectoral than any of the other genera examined. *Ophichthus*, as already mentioned, is probably on the evolutionary road to *Brachysomophis*; whether this is a primitive road for ophichthids is undeterminable.

TAXONOMY

Although internal structures must be taken into account in the basic classification of any group, particularly one as secondarily simplified as the eels, the identification and delimitation of genera and species in the group are normally based on external characters. This is particularly necessary in eels, in which the species are all too apt to be represented by unique specimens that cannot well be dissected.

The Ophichthidae in Hawaii may be recognized superficially by the fact that the fin and fin rays around the tip of the tail are either totally absent, or are much reduced as compared with the dorsal and anal fin rays immediately preceding them. In addition, the posterior nostril lies more or less below the eye, either on the inside or outside of the upper lip. The family is divided (Gosline, 1950, and this paper, above) into two subfamilies—the Myrophinae, with small rays visible externally around the tip of the tail, and the Ophichthinae, with the tail protruding as a finless fleshy point beyond the dorsal and anal. Inasmuch as I have no evidence that either of the two subfamilies is polyphyletic, the taxonomy of each will be discussed separately.

MYROPHINAE. The genera of Myrophinae have been dealt with briefly by Myers and Storey (1939) and by Schultz and Woods (1949). However, I have recently shown (Gosline, 1950, and in press) that among the genera mentioned in both of these papers there are representatives of two quite different families. Thus, *Kaupichthys* and *Chilorhinus* (and presumably *Echelus* and *Garmanichthys*) belong in a family which has little except superficial similarity in common with the Myrophinae. Of the remaining genera probably belonging to the Myrophinae, Myers and Storey (1939: 157) list seven, but Schultz and Woods (1949: 170) reduce this number to two—*Myrophis* and *Muraenichthys*. I have already pointed out (Gosline, 1950) that *Garmanichthys bicollaris* Myers and Wade must almost certainly be removed from the genus *Muraenichthys*, as interpreted by Schultz and Woods. But even with *G. bicollaris* removed, some question arises as to whether these authors have not too broadly interpreted the limits of *Myrophis* and *Muraenichthys*. It appears to me that *Muraenichthys* of Schultz and Woods should at least be divided into subgenera, one of which—*Schultzidia*—is described below.

The circumtropical subfamily includes some 25 described species of small eels.

OPHICHTHINAE. The Ophichthinae comprises one of the largest of eel groups. The genera and species of the subfamily have never been adequately revised.

Difficulties of two main sorts have discouraged recent ichthyologists from revising the subfamily as a whole. First, the group is of circumtropical distribution, but is very inadequately represented in collections. Many of the species and a good number of genera have been based on unique specimens scattered among the museums of the world, and many of the species undoubtedly remain uncollected. Second, most of the characters by which more normal fishes are distinguished are lacking in some or all of the Ophichthinae, e. g., fins, scales, and gill rakers. This has resulted in many hopelessly inadequate descriptions which would have to be properly allocated by anyone reviewing the subfamily.

Each of the three most recent treatments of the subfamily *in toto* is more than 80 years old. Kaup (1856), in his synopsis of the apodal fishes, recognized and described a plethora of genera (22) on completely insufficient, almost whimsical, bases. As all of Kaup's types, so far as I know, have never been re-examined, many of his generic and specific names remain unidentifiable. Bleeker (1865), in a brief paper reviewing the classification of all eel groups, recognized 8 genera of Ophichthinae. Günther (1870) further reduced the genera of the subfamily to 2, but recent workers have recognized many more.

Since Günther, the Ophichthinae has been investigated only piecemeal. Storey (1939) has redescribed the types of most of the species belonging to the genera *Callechelys* and *Bascanichthys*, but no other generic revisions have been attempted recently. On the other hand, the Ophichthinae of various parts of the world have been dealt with in faunistic reports. Most notable of these are probably those of Bleeker (1864) and Weber and de Beaufort (1916) for the Indo-Australian Archipelago and of Jordan and Davis (1892) for America and Europe.

Genera and species of Ophichthinae continue to be described almost every year—some well, many badly. The system of classification within the group—never adequate—is consequently now outdated and chaotic.

The Ophichthinae are found everywhere along the shores of tropical seas. In addition, some of them have been picked up at the surface of the ocean far from land; at least one, *Caecula cephalopeltis*, occurs in fresh water; and one, *Pisoodonophis boro*, is a pest in rice fields (Ramakrishna Ayyar, 1932). Most of the members are moderate to small wormlike forms, though several are large and have fang-like teeth. Most of the group seem to burrow in the sand with their tails. Some of these, e. g., *Callechelys luteus* in Hawaii, usually remain with the head and a small part of the body above the surface of the sand, while others, e. g., *Sphagebranchus platyrhyncha* in Hawaii, seem to live an almost completely subterranean existence, burrowing forward or backward through the sand with great ease and speed.

The account that follows deals with the 9 genera and 13 species of ophichthids known from the Hawaiian Islands, including Johnston Island. Specimens of all the species are either represented in the University of Hawaii Collection or have been examined in the Bishop Museum. Those represented in the University's collection have been illustrated. In the synonymies all Hawaiian records are listed, but those from elsewhere, except for the type, are not.

Certain principal taxonomic characters of the Hawaiian ophichthids are summarized in Table 2.

ARTIFICIAL KEY TO THE HAWAIIAN SPECIES OF OPHICHTHIDAE

1a. A fin with fin rays present, but reduced, around tip of tail. Species less than 18 inches in length; in Hawaiian forms dorsal originating nearer anus than gill openings, and pectoral fins absent. (Subfamily Myrophinae.)
  2a. Dorsal commencing over a head length (measured to gill opening) behind anus; body compressed, its depth about 1½ times its width; teeth lacking on intermaxillary (or premaxillary) and vomer (see Fig. 12*a*).
    1. *Muraenichthys* (*Schultzidia*) *johnstonensis*
  2b. Dorsal commencing within a head length of the anus; body nearly cylindrical; teeth present on intermaxillary and vomer.
    3a. Dorsal commencing behind anus; cleft of mouth reaching well behind eye; vomerine teeth in 2 or 3 rows.
      2. *Muraenichthys* (*Muraenichthys*) *schultzei*
    3b. Dorsal origin over or ahead of anus; cleft of mouth reaching almost to posterior border of eye; vomerine teeth in a single, sometimes irregular, row (see Fig. 12*b*).
      3. *Muraenichthys* (*Muraenichthys*) *cookei*
1b. Tip of tail a hard, fleshy point, without fin. (Subfamily Ophichthinae.)
    4a. Body without traces of fins anywhere.
      5a. Snout more or less elliptical in cross section, without lateral ridges; head (measured to gill opening) contained 15 to 20 times in the extremely elongate body; posterior nostril opening on outside of upper lip (Fig. 14*a*).
        4. *Caecula* (*Sphagebranchus*) *flavicauda*
      5b. Snout with well-developed lateral ridges, forming a flattened triangle in cross section; head contained about 10 times in body length; posterior nostril opening on inside of upper lip, the opening not visible externally.
        5. *Caecula* (*Sphagebranchus*) *platyrhyncha*

4b. Dorsal and anal present, though sometimes low and inconspicuous.
  6a. Dorsal commencing well ahead of gill openings. Lower jaw inferior.
    7a. Pectorals absent; tail (measured from anus) shorter than trunk (measured from gill openings to anus). Dorsal high, anal low.
      6. *Callechelys luteus*
    7b. Pectorals present; tail longer than trunk.
      8a. Pectoral short, rounded, its length less than the width of its base; upper lip not fringed.
        9a. Color pattern consisting of several longitudinal series of spots on sides.
          7. *Myrichthys maculosus*
        9b. Color pattern consisting of a series of about 29 dark saddles of varying depth, but on an average reaching down approximately to the lateral line.
          8. *Myrichthys bleekeri*
      8b. Pectoral considerably longer than broad; edge of upper lip fringed.
        9. *Cirrhimuraena macgregori*
  6b. Dorsal commencing about over or behind the gill openings.
    10a. Lower jaw inferior; upper lip without a series of papillae.
      11a. Anterior nostrils with leaf-like appendages (Fig. 17).
        10. *Phyllophichthus xenodontus*
      11b. Anterior nostrils without leaf-like appendages.
        12a. Body plain. Eye about equal to snout length. (This species, probably from moderately deep water, will be dealt with in a report on the fishes killed by the Mauna Loa lava flow of 1950.)
          11. Ophichthidae, new species
        12b. Body with well-marked spots or saddles.
          13a. Mouth small and distinctly inferior, the snout projecting beyond tip of lower jaw by more than two eye diameters; teeth small, completely lacking on vomer.
            12. *Leiuranus semicinctus*
          13b. Mouth large, little inferior, the snout projecting by less than an eye diameter; teeth large, sharp, present on vomer. Dorsal commencing approximately over gill opening.
            13. *Ophichthus polyophthalmus*
    10b. Lower jaw somewhat projecting; upper lip papillate or fringed. Teeth long, fang-like; eye well forward of center of cleft of mouth; dorsal commencing well behind gill opening.
      14. *Brachysomophis henshawi*

MURAENICHTHYS Bleeker

As already mentioned, the most recent paper on the genus (Schultz and Woods, 1949) interprets the limits of the genus *Muraenichthys* very broadly, including in it several genera usually recognized as distinct by previous authors. In the same paper, Schultz and Woods describe a species, *Muraenichthys johnstonensis*, which expands still further the limits of the genus as understood by them. It seems to me that *M. johnstonensis* deserves at least subgeneric rank, which it is given here under the name *Schultzidia*.

Schultzidia new subgenus

SUBGENOTYPE: *Muraenichthys johnstonensis* Schultz and Woods (1949: 172).

The species of this subgenus, as Schultz and Woods point out, differ immediately from other species of *Muraenichthys* in totally lacking teeth on the intermaxillary and vomer. Vomerine teeth are usually well developed in the Ophichthidae, and their absence has long been considered a generic character in the group—in *Leiuranus*, even by Günther (1870: 54), Schultz (1943: 14), and others; and in *Ahlia* by Jordan and Davis (1892: 639), Myers and Storey (1939: 158), and Wade (1946: 199). On the other hand, *Ahlia* has been synonymized under *Myrophis*, a genus typically with vomerine teeth, by Parr (1930: 8), Hildebrand (in Longley and Hildebrand, 1941: 17), and Schultz and Woods (1949: 171). The absence of intermaxillary teeth in *Schultzidia* is, so far as I know, unique among the Ophichthidae, though the dentition or

TABLE 2

SYNOPSIS OF CERTAIN PRINCIPAL TAXONOMIC CHARACTERS OF HAWAIIAN OPHICHTHIDAE

SPECIES	DORSAL ORIGIN	PECTORAL	TEETH	UPPER LIP
MYROPHINAE				
Muraenichthys johnstonensis	Behind anus	Absent	Villiform on maxillaries, absent on intermaxillary and vomer	Not fringed
Muraenichthys schultzei	Behind anus	Absent	Granular; mostly biserial on jaws and on vomer	Not fringed
Muraenichthys cookei	Slightly before anus	Absent	Conical; uniserial on vomer and mandible, biserial on maxillary	Not fringed
OPHICHTHINAE				
Caecula flavicauda and *C. platyrhyncha*	Fin absent	Absent	Small, sharp, depressible, and uniserial throughout	Not fringed
Callechelys luteus	Ahead of gill opening; high	Absent	Conical; uniserial in jaws, biserial on vomer	Grooved but not fringed
Myrichthys bleekeri and *M. maculosus*	Ahead of gill opening; high	Short, rounded	Granular; mostly biserial	Grooved but not fringed
Cirrhimuraena macgregori	Ahead of gill opening; low	Elongate	In adult bluntly conical; on jaws biserial, on vomer in a band	Fringed
Phyllophichthus xenodontus	Over pectoral base; low	Elongate	Absent from vomer; in jaws conical, uniserial, those of mandible directed laterally	Grooved but not fringed
Leiuranus semicinctus	Over pectoral base; low	Roundish	Absent from vomer; small, conical, uniserial elsewhere	Grooved but not fringed
Ophichthus polyophthalmus	Over pectoral base	Somewhat elongate	Large, sharp, uniserial throughout	Not fringed
Brachysomophis henshawi	Somewhat behind pectoral base	Roundish	Fang-like; uniserial on vomer and mandible; biserial on maxillary	Fringed or papillate

lack of it in this part of the mouth is undescribed for several of the species of *Muraenichthys.*

Schultz and Woods, apparently from a reexamination of the types, place *M. retropinnis* in the same group with *M. johnstonensis.* There is nothing, however, in Fowler's original description (1934: 277) to indicate whether this placement is correct.

DERIVATION OF NAME: *Schultzidia,* for Leonard P. Schultz, Curator of Fishes, U. S. National Museum.

1. **Muraenichthys (Schultzidia) johnstonensis** Schultz and Woods

Fig. 12*a*

Muraenichthys johnstonensis Schultz and Woods (1949: 172, fig. 1 and tab. 1) (Johnston Island and Bikini Atoll).

MATERIAL EXAMINED: 1 specimen, 160 mm. in total length, from the reef at Midway and 2 specimens, 84 and 102 mm., from Oahu, in the University of Hawaii Collection.

The Midway specimen agrees in all essential respects with the excellent description of the species given by Schultz and Woods. I can find in the Midway specimen no embedded teeth on the premaxillary, suggested as a possibility by these authors; in fact, an adnate upper lip covers the area in which such teeth might be expected.

The species is known only from the records listed above.

2. **Muraenichthys (Muraenichthys) schultzei** Bleeker

Muraenichthys schultzei Bleeker (1857: 366) (South Java); Fowler and Ball (1925: 5) (Johnston Island); Fowler (1928: 41) (Johnston Island).

MATERIAL EXAMINED: 8 specimens, 77–99 mm., of the 12 recorded by Fowler and Ball and by Fowler from Johnston Island in the Bishop Museum.

Except for the specimens listed above, the species is unknown in the Hawaiian Islands.

3. **Muraenichthys (Muraenichthys) cookei** Fowler

Figs. 3, 10*a*, 12*b*, 13

?Muraenichthys gymnopterus [non Bleeker], Fowler (1928: 40) (Hawaiian Islands).

Muraenichthys cookei Fowler (1928: 41, fig. 9) (Oahu); Schultz and Woods (1949: 172).

Muraenichthys laticaudata, Schultz [in part] (1943: 53); Fowler (1949: 44).

MATERIAL EXAMINED: 10 specimens from Oahu, 1 from Kauai, and 7 from Midway, all in the University of Hawaii Collection; Fowler's type of the species in the Bishop Museum.

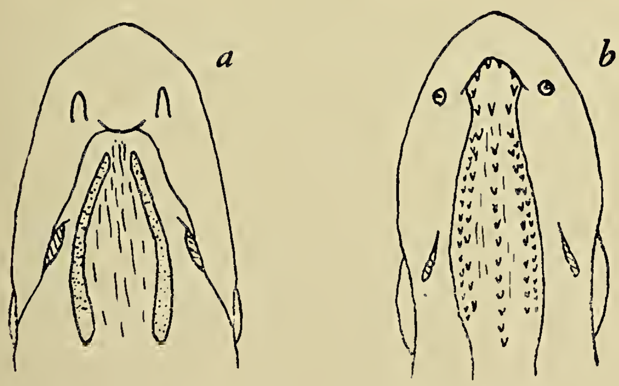

FIG. 12. *a*, Roof of mouth of *Muraenichthys* (*Schultzidia*) *johnstonensis*; *b*, of *Muraenichthys* (*Muraenichthys*) *cookei*.

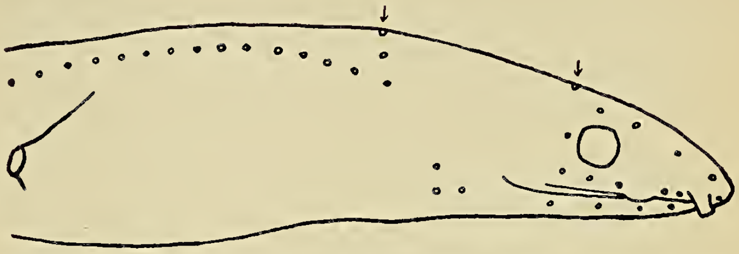

FIG. 13. Head of *Muraenichthys* (*Muraenichthys*) *cookei*. As in subsequent figures, the lateral line pores of the head are shown and those of the middorsal line are indicated by arrows.

The distinction between *M. cookei* and *M. laticaudata* is not as clear as one might wish or as Schultz and Woods's key might indicate. In my material of *M. cookei* the dorsal usually commences as much as one-third of a head length ahead of the anus, but is sometimes directly over the anus. In *M. laticaudata* the dorsal usually begins behind, but sometimes over or even slightly before the anus. There are no other readily apparent characters to distinguish the two species.

M. cookei is limited to the Hawaiian Islands and is doubtless a derivative of *M. laticaudata*. The Hawaiian offshoot is not rare. It apparently buries itself in sand-filled pockets on a coralline-rock bottom.

CAECULA Vahl

Vertical fins absent or feebly developed; if present, the dorsal commences behind the level of the gill openings. No pectoral fins in Pacific species.

Subgenus *Caecula:* with at least rudimentary vertical fins.

Subgenus *Sphagebranchus:* wholly finless.

The definition, and consequently the limits, of the genus *Caecula* are agreed upon by no two authors as far as I know. Whether the generic characterization given above is any better than many others previously proposed can be determined only from an examination of the many species in the group.

4. **Caecula (Sphagebranchus) flavicauda** (Snyder)

Table 3 and Fig. 14*a,c*

Sphagebranchus flavicaudus Snyder (1904: 516, pl. 2, fig. 4) (from between Maui and Lanai in 21 to 28 fathoms); Jordan and Evermann (1905: 80, pl. 5, fig. 2) (northeast coast of Hawaii in 50 to 60 fathoms).

A fourth specimen of this species in the University of Hawaii Collection is 516 mm. in length and was obtained from shallow water on the coral reef in Hanauma Bay, Oahu.

The posterior nostril of this species opens as an elliptical hole in the outside of the upper lip; the opening is partly covered by a flap (Fig. 14*a*). According to Weber and de Beaufort's classification of the ophichthids (1916: 280) *C. flavicauda* would key out to the genus *Hemerorhinus*. However, *Hemerorhinus* Weber and de Beaufort appears to be one of the less justified generic names in the *Caecula* group.

5. *Caecula (Sphagebranchus) platyrhyncha* new species

Table 3 and Figs. 1, 14*b*,*d*

?Caecula flavicauda [non *Sphagebranchus flavicaudus* Snyder], Fowler (1928: 47) (Kahala, Oahu; one headless specimen).

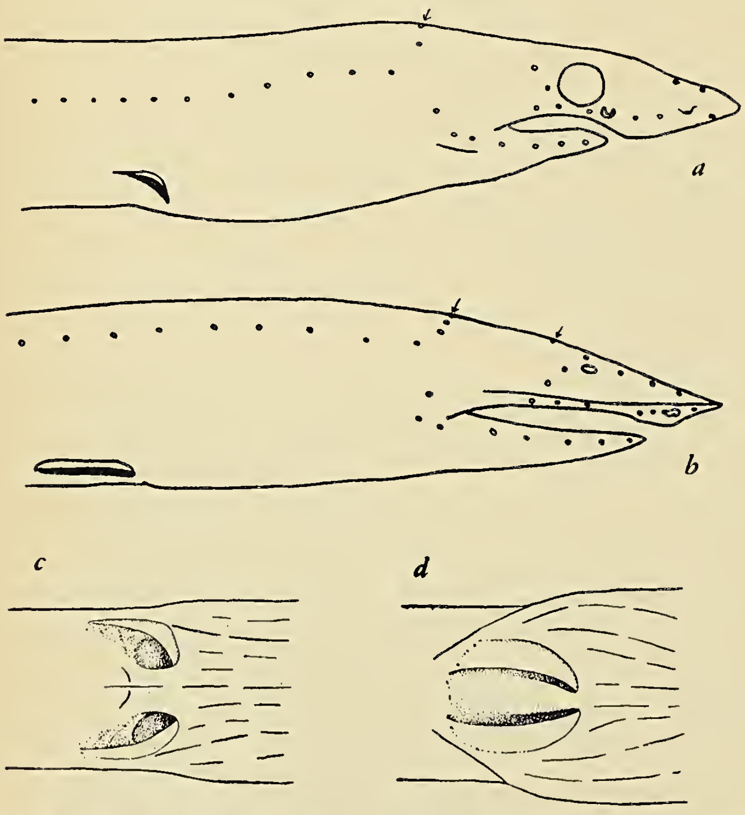

FIG. 14. *a*, Head, and *c*, ventral view, of gill openings of *Caecula* (*Sphagebranchus*) *flavicauda; b* and *d*, same views of *Caecula* (*Sphagebranchus*) *platyrhyncha.*

HOLOTYPE: U.S.N.M. No. 152543, 430 mm. in length, taken in a shallow-water poison station at Hauula Park, north shore of Oahu, T. H., on June 28, 1949, by Gosline and party.

PARATYPES: University of Hawaii No. 316, 10 specimens, 155 to 365 mm. in length, taken with the holotype; University of Hawaii No. 958, 9 specimens, 305–375 mm., taken by Needham and Welsh, July, 1949, at Hanalei, Kauai; U.S.N.M. No. 152544, 3 specimens, 164–355 mm., from a tide pool opposite Pupukea, Waimea coast, Oahu, T. H., collected by Gosline and party, Nov. 22, 1948; Bernice P. Bishop Museum No. 5543, 1 specimen, 455 mm., from Laie, north coast of Oahu, Dec. 17, 1949, collected by Sam Cooke.

A relatively short, sturdy species for the subgenus, with both ends sharply pointed. Snout forming a flattened triangle in cross section, with well-developed lateral ridges; remainder of body more or less cylindrical. Anus somewhat forward of center of length. Eye minute, embedded, and little protruding, but readily visible from the exterior, situated approximately over center of distance from tip of snout to rictus and over forward part of cleft of the inferior mouth. Anterior nostril within a very slightly raised rim on the flattened lower surface of the rostrum, its diameter about equal to the width of the eye. Posterior nostrils opening from the inside of the upper lip into the mouth, slightly before eye, not visible from the exterior. Upper lip with a deep median groove, within which lie the intermaxillary teeth. All the teeth depressible backwards, apparently not implanted in sockets in the jaws, uniserial throughout. About 5 teeth in the intermaxillary, 11 on the vomer, 15 on each maxillary, and about 20 on each side of the lower jaw. Sensory pores of head and body very prominent. Gill openings close together (separated forward by an isthmus about an eye diameter in width), nearly parallel (lines projected forward from their inner surfaces

TABLE 3

PROPORTIONAL MEASUREMENTS (EXPRESSED AS THOUSANDTHS OF THE TOTAL LENGTH) AND PORE NUMBERS FOR HAWAIIAN SPECIES OF *Caecula*

CHARACTER	*Caecula platyrhyncha*							*C. flavicauda*
	HOLOTYPE	PARATYPES, U. H. 316						U. H. 378
Total length in mm	430	365	315	274	251	207	155	413
Snout to anus	440	424	422	442	433	421	438	538
Snout to gill opening	90	87	86	87	86	90	91	46
Snout to rictus	32	31	31	36	32	34	33	17
Snout to tip of upper jaw	13	13	10	12	14	13	13	9
Snout length	17	15	15	18	17	23	19	10
Eye diameter	3	3	3	4	5	4	5	3
Greatest diameter of gill opening	16	16	19	11	14	14	15	7
Least width of isthmus	3	2	3	4	3	4	6	3
Depth of head	29	29	29	34	30	30	37	17
Depth of anus	21	24	29	27	21	20	19	9
Width of head	28	28	32	29	27	26	36	12
Width of anus	22	22	29	26	23	23	22	11
Lateral-line pores on body	118	121	120	121	121	119	120	153

would meet at an angle of about 25°), and with well-developed membranes covering the outer portions (Fig. 14*d*). Color uniformly pinkish. The specimens have all been taken from sand in shallow water, in which they were originally completely buried.

C. platyrhyncha can be immediately separated from the only other Hawaiian species of the genus by the shorter, more robust body, flat snout, and interior exit for the posterior nostrils. Distinguishing it from other nominal species is more difficult, for a large number of these wormlike, rather characterless eels have been described in a completely undiagnostic way. One such is the subgenotype—*Sphagebranchus rostratus* Bloch (1795)—which has the added feature of being of uncertain origin. (Concerning Bloch's type, Jordan and Evermann, 1896: 373, state: "According to Bloch his type came from the East Indies. Schneider (1801) corrects the locality to 'rivers of Surinam'. We have no means of knowing which record is correct."). However, Bloch states that the anus is in the middle of the body. His plate shows no membranes over the gill opening, and the eye over the middle of the cleft of the mouth. Bloch's species differs from *C. platyrhyncha* in all three of these characters.

There seems to be no described species in Oceania to which *C. platyrhyncha* is closely related. In the Indo-Australian region *Caecula vulturus* (Weber and de Beaufort, 1916: 319), from near Sumatra, appears to be most similar. However, *C. vulturus* is said to be a somewhat slenderer fish with a conical snout and with the posterior nostril opening below the eye. *Sphagebranchus selachops* Jordan and Gilbert from Cape San Lucas, the most similar species from the Eastern Pacific, appears, from Myers and Wade's treatment (1941: 75), to lack membranes over the gill openings.

DERIVATION OF NAME: *platy*, flat; *rhyncha*, snout.

CALLECHELYS Kaup

For the purposes of the present paper the genus may be sufficiently defined as follows: Dorsal and anal fin present, the former commencing ahead of the gill openings. Pectoral fins absent.

6. **Callechelys luteus** Snyder

Fig. 15*a*

Callechelys luteus Snyder (1904: 517, pl. 3, fig. 5) (Molokai); Jordan and Evermann (1905: 86, pl. 8, fig. 1) [on the type]; Storey (1939: 69, tab. 1, fig. 2) [on the type].

Ophichthys marmorata, Günther (1910: 404) (Hawaii).

Callechelys marmoratus, Fowler (1928: 43) (Honolulu market).

MATERIAL EXAMINED: 2 specimens from Oahu, 1090 and 560 mm. in total length. The larger was grabbed by hand by Mr. V. E. Brock as it rested mostly buried in the sand; the smaller swam into a night light.

To enable comparison with the data on the genus assembled by Storey (1939), the following characters of the two specimens mentioned above are given, those for the smaller in parentheses. Greatest depth 40.8 (49.6), head to gill opening 18.5 (18.8), trunk 1.8 (1.9), and tail contained 2.5 (2.3) times in total length; head 10.0 (9.7) and tail 1.3 (1.2) in trunk; snout to rictus 3.6 (3.9) and snout to dorsal origin 2.8 (2.8) in head; distance between gill openings 1.3 (1.2) in length of gill openings; angle of gill openings 130° (125°). In these characters my two specimens check far better with Storey's data on *C. luteus* than on *C. marmoratus* or *C. guichenotii*.

MYRICHTHYS Girard

In the Hawaiian region the genus may be sufficiently distinguished as follows: Dorsal commencing forward of the gill openings. Pectoral present, its base broader than its length. Teeth blunt and granular.

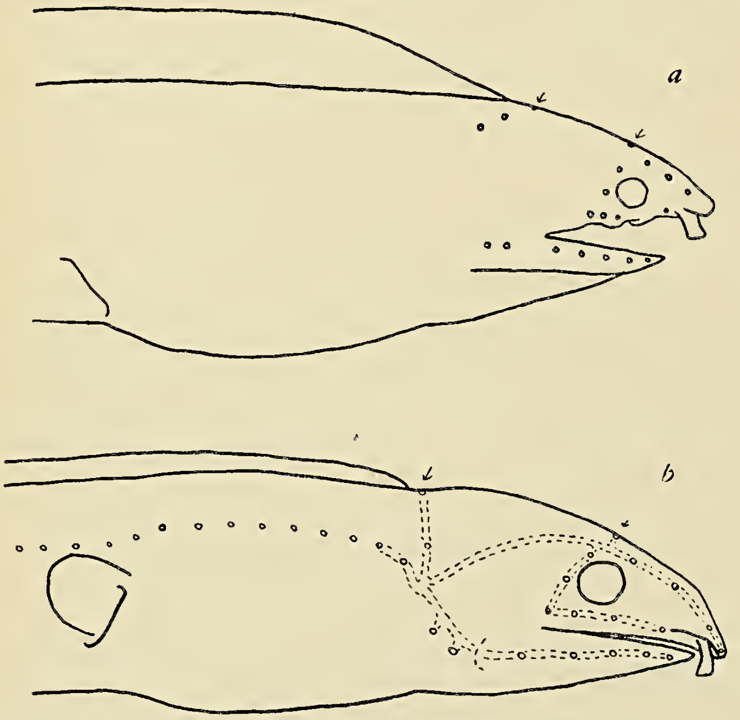

FIG. 15. *a*, Head of *Callechelys luteus*, and *b*, of *Myrichthys maculosus*, with the lateral line system of the head indicated.

7. **Myrichthys maculosus** (Cuvier)

Figs. 5, 7, 8, 9, 15*b*

Muraena maculosa Cuvier (1817: 232) (European seas?).

Pisoodonophis magnifica Abbott (1861:476) (Hawaiian Islands).

Ophichthus stypurus Smith and Swain (1882: 120) (Johnston Island).

Myrichthys magnificus, Fowler (1901: 494, pl. 18, fig. 3) [on Abbott's type]; Jordan and Evermann (1905: 84) (Hawaiian Islands).

Myrichthys stypurus, Jordan and Evermann (1905: 85, fig. 19) [on Smith and Swain's type].

Ophichthys maculosus, Günther (1910: 40) (Hawaiian Islands).

Myrichthys maculosus, Fowler and Ball (1925: 6) (Johnston Island); Fowler (1928: 43) (Johnston Island and Honolulu).

MATERIAL EXAMINED: 13 specimens from Oahu and 1 from Midway in the University of Hawaii Collection; 1 specimen from Honolulu in the Bishop Museum.

This species seems to be distributed from the Red Sea to Hawaii. It has been taken in the Phoenix (Schultz, 1943: 14) and Line Islands (Fowler, 1927: 5) south of Hawaii, as well as at Johnston Island.

8. *Myrichthys bleekeri* substitute name

Ophisurus fasciatus var. *semicinctus* Bleeker [non *O. semicinctus* Lay and Bennett (1839: 66) non *O. semicinctus* Richardson (1844: 99)] (1864: 64) (Indonesia).

Myrichthys colubrinus, Fowler and Ball (1925: 5) (Johnston Island); Fowler (1928: 42) (in part; the Johnston Island specimens).

MATERIAL EXAMINED: 8, 335–385 mm., of the 12 specimens recorded by Fowler and Ball and by Fowler from Johnston Island, in the Bishop Museum Collection.

These specimens agree well with the diagnosis of this species as given by Schultz (1943: 12).

The records cited are the only ones for the species in the Hawaiian Islands. Schultz (1943: 12) has taken it at Palmyra.

Bleeker's original name is a homonym, for which a substitute is here proposed.

CIRRHIMURAENA Kaup

Dorsal and anal low, the dorsal beginning before, over, or behind the gill openings. Pectorals well developed. Upper lip with a fringe. No canines, the maxillary and vomerine teeth either biserial or in bands.

Cirrhimuraena is here broadly defined. Whether all the species included in the definition are congeneric or even monophyletic is impossible to say without examination of specimens. They appear to fall into three groups, for each of which a generic name has been proposed as follows:

Cirrhimuraena Kaup (1856: 27). Dorsal commencing over or behind gill openings. Pectorals elongate. Eye forward of center of cleft of mouth. Maxillary teeth in bands. Included species: *C. tapeinopterus*, *chinensis*, and *chilopogon*, reviewed in Weber and de Beaufort (1916: 291).

Jenkinsiella Jordan and Evermann (1905: 83). Dorsal commencing well ahead of gill opening. Pectorals elongate. Eye about over center of cleft of mouth. Maxillary teeth biserial. Included species: *Microdonophis macgregori* Jenkins (1904: 422) and *Jenkinsiella oliveri* Seale (redescribed by Herre, 1923: 165).

Calamuraena Whitley (1944:261). Dorsal commencing well ahead of gill openings. Pectorals short, rounded. Eye more or less over center of cleft of mouth. Maxillary teeth mostly biserial. Included species: *Ophichthys calamus* Günther (1870: 74).

9. **Cirrhimuraena macgregori** (Jenkins)

Figs. 6, 10*b*, 16

Microdonophis macgregori Jenkins (1904: 422, fig. 2) (Maui); Jordan and Evermann (1905: 82, fig. 18) [on the type].

Ophichthus calamus, Fowler (1928: 45) (Maui).

MATERIAL EXAMINED: 4 specimens from Oahu and 2 from Hawaii in the University of Hawaii Collection; 1, recorded above by Fowler, from Maui in the Bishop Museum.

Contrary to the descriptions of Jenkins, Jordan and Evermann, and Fowler, this species does not have the teeth "in a single series on vomer and in jaws." In the larger University of Hawaii specimens, 188–338 mm., the teeth on the vomer are in several series, particularly toward the rear (Fig. 6*b*); those in the jaws are partly uniserial, partly biserial. In the Maui specimen, 131 mm. long, the teeth on the vomer are biserial behind, uniserial in front, and those on the jaws appear as single irregular rows. In other respects my specimens agree with the descriptions cited above. The fringe on the upper lip is somewhat better developed than is indicated in Jenkins' figure, reissued in Jordan and Evermann.

That Fowler erred in synonymizing this species with *Ophichthus calamus* Günther is clearly indicated by Whitley's redescription and figure of the latter species (1944: 261, fig. 6). Actual relationships appear to be closer between *C. macgregori* and *C. oliveri* (Seale) as redescribed by Herre (1923: 165, pl. 2, fig. 2). However, *C. oliveri* is said to have the "vomerine teeth in two rows, merging into one row posteriorly." Herre's plate shows the pectorals as tapering to a point, which also is not true of *C. macgregori*.

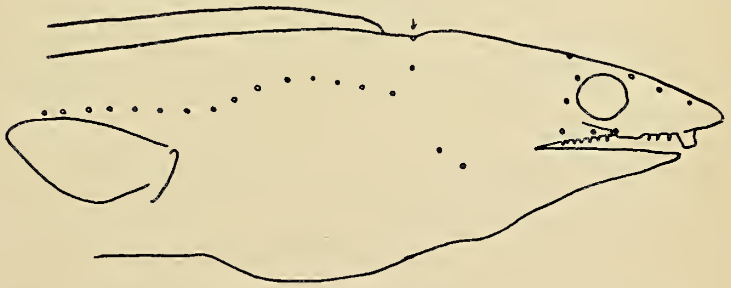

FIG. 16. Head of *Cirrhimuraena macgregori*.

PHYLLOPHICHTHUS new genus

GENOTYPE: *Phyllophichthus xenodontus*, new species.

Head and body subcylindrical, becoming compressed toward tip of tail. Anus about at center of length. Dorsal and anal low, discontinuous around tip of tail which protrudes as a fleshy point. Dorsal commencing over rear of pectoral bases. Pectorals well developed, elongate. Gill openings round orifices opening onto lower part of pectoral bases. Branchiostegal rays numerous, those of the two sides overlapping. Mouth inferior to the long, tapering snout. Anterior nostrils with posterior borders extending downward into leaflike appendages. Posterior nostrils opening into mouth under a broad, infolded flap which is delimited on the outside of the upper lip as a groove below the anterior border of the eye. Two rows of conical teeth on the intermaxillary plate. A single row of smaller teeth on the inner border of each maxillary. No vomerine teeth. Mandibular teeth large, uniserial, well outside of the maxillary teeth, and projecting directly laterally.

Both the leaflike appendages of the anterior nostrils and the dentition of this genus will distinguish it from all other ophichthids. Nasal appendages, though common in the Muraenidae, are little developed elsewhere in the family Ophichthidae, though flaring, tubular nares are indicated for *Chlevastes* by Aoyagi (1943?: 16, fig. 5). In dentition *Phyllophichthus* most closely resembles *Leiuranus*, but the latter genus has normal, upright mandibular teeth. *Phyllophichthus* would appear to be a specialized relative of the *Leiuranus*-*Machaerenchelys* stock.

DERIVATION OF NAME: *phyll*, leaf; *Ophichthus*, the type genus of the family.

10. *Phyllophichthus xenodontus* new species

Fig. 17*a,b*

HOLOTYPE: University of Hawaii No. 318, 240 mm. in total length, taken in a poison station from shallow water at Hauula Park, Oahu, T. H., June 28, 1949, by Gosline and party.

DESCRIPTION (all measurements given as thousandths of the standard length): Distance from tip of snout to anus 512, to gill opening 96, to dorsal origin 101, to tip of lower jaw 10, to eye 28; greatest depth 31, depth at anus 22; greatest width 25, width at anus 20; eye 11; fleshy interorbital 12; length of nasal flap 7; cleft of mouth 38; greatest diameter of gill opening 9; width of pectoral base 9; and length of pectoral 26.

Pores in lateral line about 160.

Snout long, tapering to a conical point. Eye well developed, its posterior border nearly over rictus. Cleft of the inferior mouth horizontal, long, and narrow. Groove on under surface of snout (in which lie the intermaxillary teeth) extending nearly to tip of snout. Anterior nostrils about at level of tip of lower jaw, close together, their flaps touching one another. Intermaxillary teeth well developed, conical, arranged as 5 pairs in parallel longitudinal rows. About 4 weak teeth on the inner edge of each maxillary before posterior nostril, 4 or more even weaker embedded teeth behind. Lower jaw with a row of some 18 strong laterally directed teeth on each side; these rows not continued forward around the toothless symphysis. Color of

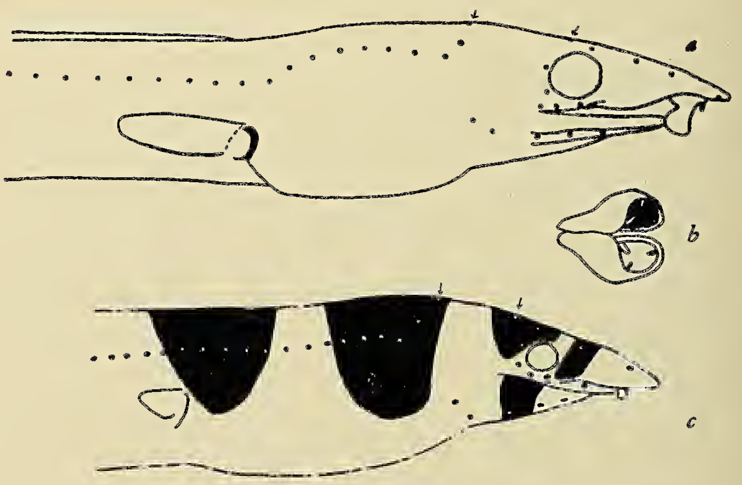

FIG. 17. *a*, Head and *b*, inferior view of anterior nostrils of *Phyllophichthus xenodontus*; *c*, head of *Leiuranus semicinctus*.

head and body in life plain greenish, darker above.

DERIVATION OF NAME: *xen*, strange; *odontus*, toothed.

LEIURANUS Bleeker

Vomerine teeth lacking. Dorsal beginning well behind head. Pectorals small. No nasal appendage.

One species: *Leiuranus semicinctus*.

12.[3] **Leiuranus semicinctus**

(Lay and Bennett)

Figs. 4, 17*c*

Ophisurus semicinctus Lay and Bennett (1839: 66, pl. 4, fig. 4) (Oahu).

Leiuranus semicinctus, Fowler (1901: 494) (Hawaiian Islands); Snyder (1904: 516) (Honolulu); Fowler and Ball (1925: 6) (Johnston Island).

MATERIAL EXAMINED: 2 specimens from Oahu in the University of Hawaii Collection; 2 specimens from Oahu and 2 from Johnston Island in the Bishop Museum Collection.

Among Hawaiian forms, the color pattern of this fish could be confused only with that of *Myrichthys bleekeri*.

OPHICHTHUS Thunberg and Ahl

For purposes of the present paper *Ophichthus* may be defined as follows: Dorsal fin commencing over or behind gill opening. Pectorals present. Conical teeth present on jaws and vomer. Lower jaw somewhat inferior.

13. **Ophichthus polyophthalmus** (Bleeker)

Ophichthys polyophthalmus Bleeker (1864: 43) (Amboina); Fowler (1927: 5) (Kahoolawe); Fowler (1928: 45) (Honolulu market).

Microdonophis fowleri Jordan and Evermann (1904: 164) (Honolulu market); Jordan and Evermann (1905: 82, pl. 6) (Honolulu market); Jordan and Snyder (1907: 208) (Honolulu market).

Microdonophis polyophthalmus, Jordan and Snyder (1907: 208) (Honolulu market).

MATERIAL EXAMINED: 1 specimen in two pieces, recorded by Fowler (1928), from Kahoolawe, in the Bishop Museum.

The teeth in this specimen are large and sharp, in very regular uniserial series on the jaws and vomer. I can find little trace of the fringe on the upper lip described by Jordan and Evermann, and the lower jaw is more inferior than shown on their plate.

BRACHYSOMOPHIS Kaup

Lower jaw protruding beyond the upper. Large canine teeth in the jaws and on vomer. Eye far forward on snout. Upper lip fringed.

The taxonomic problems in regard to *Brachysomophis* have recently been pointed out by Schultz (1943: 17).

14. **Brachysomophis henshawi**

Jordan and Snyder

Figs. 2, 18

Brachysomophis henshawi Jordan and Snyder (1904: 910) (Honolulu); Jordan and Evermann (1905: 84, pl. 7) [on the type]; Fowler (1928: 46) [on the type].

MATERIAL EXAMINED: 1 specimen, without locality but most probably from Oahu, inherited by the University of Hawaii Collection.

DISTRIBUTION OF THE OPHICHTHIDAE IN THE HAWAIIAN ISLANDS

The records of the Ophichthidae in the Hawaiian Islands are in agreement with the

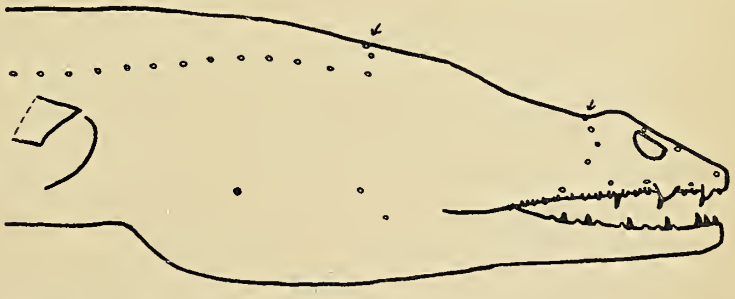

FIG. 18. Head of *Brachysomophis henshawi*. The pectorals of the only available specimen are broken.

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[3] For reference to species 11, see key, page 309.

little that is already known of fish distribution in these islands. The predominance of records from Oahu simply reflects the overwhelming proportion of collecting done there. The question remains unsolved whether the Hawaiian fish fauna arrived originally in the low leeward islands and moved from there into the high windward islands after they arose (as postulated for much of the terrestrial biota by Zimmerman, 1948) or whether the present fish fauna came directly to these high islands. That Johnston Island has been a way point in the immigration, and perhaps the emigration, of much, at least of the Hawaiian, fish fauna is indicated by the Ophichthidae, as well as by numerous other groups. The relationship, if any, between the ophichthid eels (and other fish groups) of the Hawaiian chain and those of Wake, as demonstrated by Edmondson (1925) for Crustacea, remains unknown.

The known distribution of Hawaiian ophichthids is shown in Table 4. Such a table may be very misleading for two reasons. (1) It is strongly weighted by the incidence of collecting in the various areas. The low number of recorded species from the leeward Hawaiian Islands, for example, is undoubtedly due to inadequate collecting. Actually, for the areas listed, collecting has probably been done most adequately on the high Hawaiian Islands, less so on the Phoenix and Line Islands, even less on Johnston Island, and least adequately on the leeward Hawaiian group. (2) Such a table may well reflect an author's predilection for "splitting" or "lumping." Of the species listed in Table 4, *Callechelys luteus* and *Muraenichthys cookei* have been and could well be considered synonyms of more wide-ranging species. On the other hand, the Hawaiian specimens of the species here called *Ophichthus polyophthalmus*, described from the East Indies, may well be a distinct species.

Nevertheless, the table does bring out several points. (1) The fact that 7 out of 13 species (and one genus) of Ophichthidae known from the Hawaiian Islands have not been recorded elsewhere indicates the high degree of differentiation of the Hawaiian fish fauna. A similar but probably somewhat lower degree of endemism holds for other fish groups. (2) The species endemic to Hawaii have not yet been taken at Johnston Island. Two species taken at Johnston have not yet been taken elsewhere in the Hawaiian group, but all four species recorded from Johnston are widely distributed in the Indo-West Pacific. This would point—insecurely to be sure—to Johnston Island as a portal for the immigration into Hawaii of wide-ranging Pacific species, but not as a portal for emigra-

TABLE 4

DISTRIBUTION OF HAWAIIAN OPHICHTHIDS

SPECIES	HAWAIIAN ISLANDS			PHOENIX AND LINE ISLANDS	ELSEWHERE
	HIGH	LEEWARD	JOHNSTON		
1. *Muraenichthys johnstonensis*	X	X	X		Bikini
2. *Muraenichthys schultzei*			X	X	Red Sea to Ellice Islands
3. *Muraenichthys cookei*	X	X			
4. *Caecula flavicauda*	X				
5. *Caecula platyrhyncha*	X				
6. *Callechelys luteus*	X				
7. *Myrichthys maculosus*	X	X	X	X	Red Sea to Oceania
8. *Myrichthys bleekeri*			X	X	East Indies
9. *Cirrhimuraena macgregori*	X				
10. *Phyllophichthus xenodontus*	X				
*12. *Leiuranus semicinctus*	X		X	X†	Southern Africa to Samoa
13. *Ophichthus polyophthalmus*	X				East Indies and ?Society Islands
14. *Brachysomophis henshawi*	X				

* For reference to eleventh species, still unnamed, see key, page 309.

† Taken by the author at Hull Island.

tion, i. e., in Simpson's terminology (1940: 148) Johnston would appear to be a primarily one-way "filter bridge" for fishes. This also is borne out in other fish groups. (3) There is no close relationship between the Hawaiian ophichthids and those of the West Coast of America. This, also true of other small fishes, checks well with Ekman's "East Pacific barrier" hypothesis (Ekman, 1935: 105).

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The Distribution of Eggs and Larvae of the Anchovy, *Stolephorus purpureus* Fowler, in Kaneohe Bay, Oahu, with a Consideration of the Sampling Problem[1]

Albert L. Tester[2]

INTRODUCTION

A small species of anchovy, *Stolephorus purpureus* Fowler,[3] known locally as the "nehu," is used extensively as livebait in the skipjack (*Katsuwonus pelamis*) fishery of Hawaii. Although the nehu is caught in several different baiting areas throughout the Territory, it is fished most heavily and is taken in largest quantity in Kaneohe Bay, on the east shore of Oahu. In the daytime the fish are caught by surround nets in shallow, turbid water alongshore, often close to the mouths of streams. After dark they are caught by night lighting in deeper and less turbid water farther out in the bay.

Without doubt, the availability of nehu is one of the main factors governing the size of the skipjack catch. In recent years, coincident with an increased fishing effort, there has been an alleged decrease in the availability of nehu in the most important baiting area—Kaneohe Bay. The question has been raised as to whether or not this decrease indicates overfishing of the nehu population.

In 1948, an intensive study of the nehu of Kaneohe Bay was initiated to determine essential biological information which might lead eventually to knowledge of the level of fishing intensity for maximum sustained yield. The present report deals with one phase of this study, namely, the distribution of nehu eggs and larvae throughout the waters of the bay. The investigation must be regarded as preliminary in nature. It was undertaken partly to determine an efficient sampling procedure for future work, and partly to obtain general information on the early life history of the nehu and the distribution of eggs and larvae.

Acknowledgments: The chief responsibility for the field work devolved upon Mr. Lester Zukeran, skipper of the University of Hawaii's research vessel *Salpa*, who located the stations, navigated the ship over the courses, and assisted in the hauling and washing-down of the nets with unending patience and skill.

Two large plankton nets were loaned to us through the courtesy of Mr. Vernon E. Brock, Director of the Division of Fish and Game, Territorial Board of Agriculture and Forestry.

Several graduate students of the University of Hawaii assisted in various phases of the work. Mr. Kenji Ego assisted in Surveys 1 and 2, Mr. Daniel Yamashita in Surveys 1*a*, 1*b*, 2, 3, and 4, and Mrs. Bertha Cutress in Surveys 3 and 4. The monotonous and difficult job of microscopic examination of the plankton samples, including the identification and segregation of the eggs and larvae and the measurement of the larvae, was undertaken with dispatch and efficiency by Mrs. Cutress, assisted on occasion by Mr. Yamashita. Chlorinity and oxygen determinations were made in part by Miss Winnifred Tseu and in part by Mr. Yamashita.

I wish to express my sincere thanks to those

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[1] Contribution No. 12, Hawaii Marine Laboratory. Submitted for publication April 2, 1951.

[2] Department of Zoology and Entomology, University of Hawaii.

[3] The status of the generic name has been discussed by Gosline (1951).

individuals who assisted actively in the work and to members of the staff of the Department of Zoology and Entomology, University of Hawaii, who have made helpful suggestions.

PHYSICAL FEATURES OF KANEOHE BAY

Kaneohe Bay (Fig. 1), on the windward (east) shore of Oahu, is about 7 miles in length and about 2 miles in width. It lies in a general northwest-southeast direction and has a total area of about 12 square miles.

For the most part, a continuous but irregularly indented coral reef follows the shoreline and averages about 400 yards in width. It is broken at the mouths of streams by mud flats. The main body of the bay is studded with coral reefs of various sizes and shapes. At low tide these, and also the shoreside reef, are either awash or are covered by about a foot of water; at high tide they are covered by 3 or 4 feet of water. In some places, e.g., the southern sector of the bay, the reefs have been removed by dredging. Deducting the area of the coral reefs and flats from the total, the navigable water area is about 6 square miles.

The southern sector of the bay, which averages about 40 to 45 feet in depth, is protected from the open sea by Mokapu Peninsula. The middle sector of the bay is partially protected from the open sea by coral reefs and by a large sand flat, known as Sand Island, which is partly exposed at some phases of the tide. Within the middle sector, the channels between the reefs average about 40 feet in depth. The northern sector of the bay is also partially protected from the outer sea by sand shallows and coral reefs, although not to the same extent as the southern and middle sectors. Its average depth is less than that of the other two sectors, about 15 to 20 feet.

Thus, apart from a few shallow channels, Kaneohe Bay is virtually cut off from direct interchange with the outer ocean. Although surface water will flow over the shallows and enter the bay, propelled by the strong northeast trade winds, the bay would be expected to have a variety of simple to complex internal circulatory systems, each depending on the configuration of the shoreline, the presence of reefs, the strength of the wind, the phase of the tide, and the amount of fresh water entering the bay from several small streams.

In the southern and middle sectors, the water has a brownish tinge, indicating the presence of silt and, perhaps, plankton. It is quite cloudy alongshore where a strong turbulence is created by the usual onshore wind. In the northern sector, the water close to shore is also somewhat brownish and cloudy. However, the blue ocean water, entering through the main northern channel, impinges on the bay water and, on occasion, forms a definite line of demarcation.

STATIONS AND SURVEYS

Twenty-three stations in representative locations were selected from a chart of Kaneohe Bay, nine (Stations 1 to 9) in the southern sector, eight (Stations 10 to 17) in the middle sector, and six (Stations 18 to 23) in the northern sector (Fig. 1). The stations were not spot locations; rather, they were straight or sinuous courses followed by the research vessel *Salpa* in towing plankton nets. The straight courses were followed in the more open parts of the bay; the sinuous courses were necessary at stations located among the coral reefs. As nearly as possible, the same course was followed at each station during successive surveys.

Four main surveys were undertaken on the following dates: (1) September 6, 7, and 8, 1949, (2) December 27, 28, and 29, 1949, (3) March 16, 17, and 18, 1950, and (4) June 21, 22, and 23, 1950. In each survey, the stations of each sector were worked on successive days. In addition, two interim surveys were made in the vicinity of Station 4 as follows: (1*a*) November 25, 1949, and (1*b*)

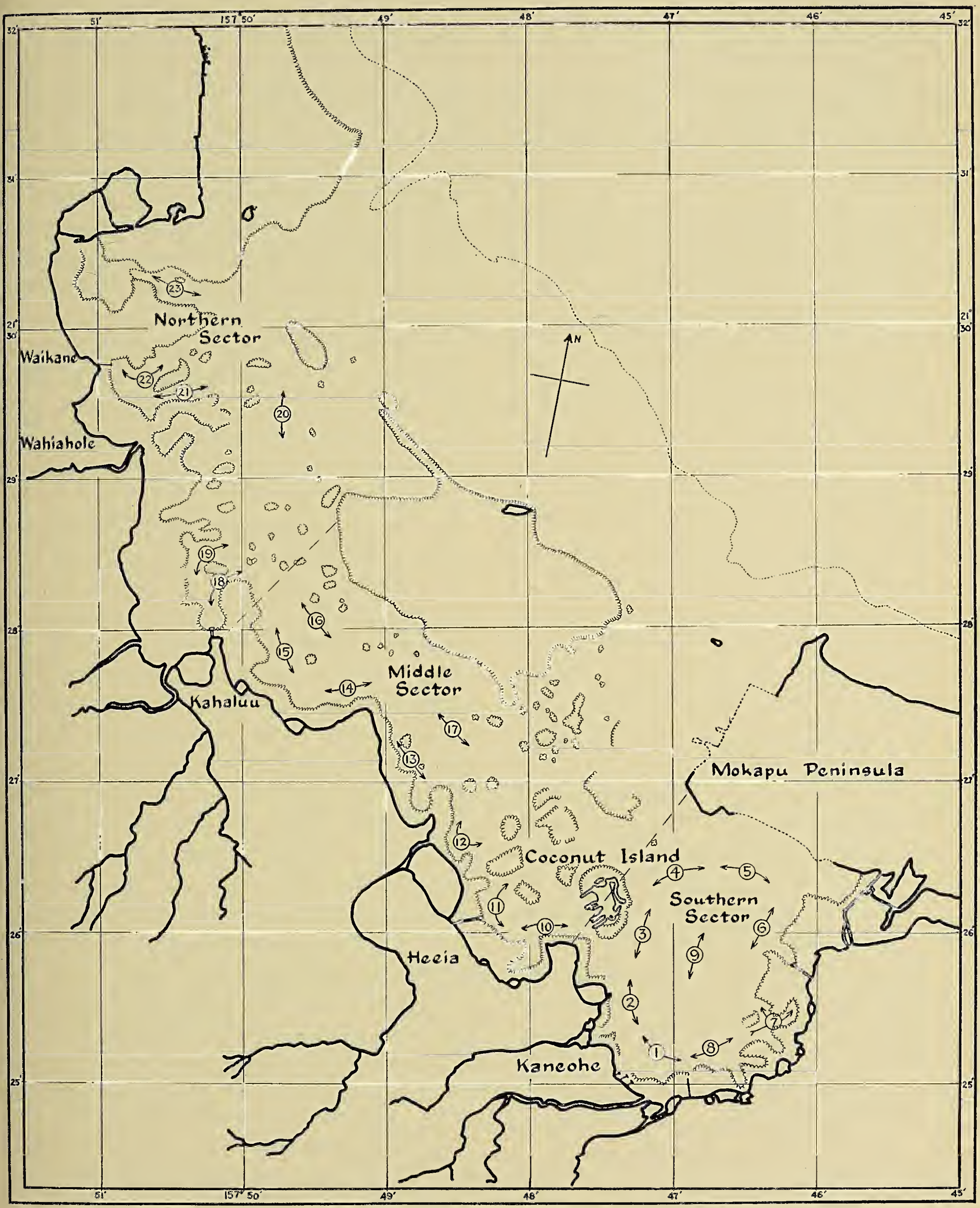

FIG. 1. Map of Kaneohe Bay showing place names, sectors, and stations.

December 8, 1949. Casual hauls were also made irregularly throughout the year at various stations in the southern sector.

NETS AND HAULS

Three different plankton nets were used, which are hereafter referred to by the diameter of their mouth openings: 100 cm., 22 cm., and 12.3 cm.

The 100 cm. net had an overall length of about 5 meters. The forward part, 180 cm. in length and 100 cm. in diameter, was made of fish net of 1.5 cm. stretched mesh, and was fastened to the net ring with a 25 cm. strip of canvas. The forward part was lined with an inner skirt of No. 24 grit gauze (0.81 mm. aperture) which was fastened to the canvas forward, but was free aft. The middle part of the net was 100 cm. in length and 100 cm. in diameter. It was made of No. 24 grit gauze and was fastened to the forward part with a 20 cm. strip of canvas. The after part of the net was 190 cm. in length and tapered in diameter from 100 to 9 cm. It was made of No. 40 grit gauze (0.47 mm. aperture) and was attached forward to the middle part and aft to a 9 cm. detachable net band by small strips of canvas. The cod end, 30 cm. in length and 9 cm. in diameter, was also made of No. 40 grit gauze, and was fastened to the net band with a canvas strip.

The 22 cm. net was a simple conical net made of No. 2 Dufour bolting silk (0.35 mm. aperture). Its overall length was 50 cm. The forward part was fastened to the net ring with canvas, and the after end was tied with tape rather than having a detachable cod end.

The 12.3 cm. net was a regular Clarke-Bumpus (Clarke and Bumpus, 1940), with a closing device (which was not used) and a current meter. It was also made of No. 2 Dufour bolting silk.

In the four main surveys two nets, the 100 cm. and either the 22 cm. (Surveys 1, 3, and 4) or the 12.3 cm. (Survey 2), were hauled simultaneously at slow speed just below the surface. The large net was towed from the boom, which was slung out on the starboard side, whereas the small net was towed directly astern. Each haul was of exactly 10 minutes duration. The hauls at each station were made in duplicate, one in one direction (A) and the other in the opposite direction (B) following a reversed course. As nearly as can be determined by timing chips of wood as they passed from bow to stern, the ship's speed varied from 1.8 to 2.2 knots. The slower speeds resulted when towing against the wind, and the faster speeds when towing with the wind.

In the two interim surveys, two identical 22 cm. nets were used, one towed just below the surface and the other at a depth. To avoid the wash of the ship's propeller, the towlines were fastened to a spar which projected horizontally from the port side of the vessel, forward of amidships. The depth was adjusted by fastening lead weights to the net ring and by varying the length of towline. The depth was estimated by calculation, knowing the length of line and the angle of stray. The closing Clarke-Bumpus net was not used for hauls at a depth because of the danger of snagging on the uneven bottom. Further details on haul number, direction, and spacing will be given in a later section of this report.

After each haul, the 100 cm. net was washed with sea water from a pressure hose to concentrate the plankton in the cod end. The smaller nets were jerked upward and downward in the water to accomplish the same purpose. The plankton material was then transferred to quart jars (100 cm. net) or pint jars (22 and 12.3 cm. net), and formalin was added for preservation. To prevent contamination from station to station, the 100 cm. net was towed inside-out, with the cod end removed, between stations. The smaller nets were washed thoroughly in sea water between hauls.

In a few cases, when an exceptionally large catch was made with the 100 cm. net, a small quantity of plankton was lost in attempting to transfer the material from the cod end to the jar. Loss from this source would not affect the general conclusions appreciably. During the course of each day's operation, there was a steady accumulation of inert organic material on the silk of the 100 cm. net. It was impossible to remove this either by use of the pressure hose or by towing the net inside-out between stations. It could be removed only by scrubbing the net with a brush at the end of the day. This would probably cause a small but progressive decrease in efficiency from station to station within days. During the first 2 days of Survey 1, barnacles on the ship's bottom caused small rips in the silk of the 100 cm. net, which doubtless decreased its efficiency. These were sewn prior to the third day of Survey 1, and snagging of the net was henceforth avoided. The original old, weak grit gauze was replaced with new for Surveys 3 and 4.

Apart from towing the nets in an identical manner and for exactly the same length of time for each haul, no serious attempt at quantitative sampling was made. In Survey 2, meter readings were taken with the 12.3 cm. net. In Surveys 3 and 4, the meter of the 12.3 cm. net was towed behind the boat, and readings were taken for each haul. However, except where indicated, adjusted data are not presented because (1) comparable adjustments are not available for all surveys, (2) the adjusted data, where available, do not differ greatly from the unadjusted data, and (3) the variation between identical hauls at the same place from day to day probably would be of much greater magnitude than the variation induced by slight differences in quantity of water strained from haul to haul on the same day.

PHYSICAL AND CHEMICAL DATA

During each of the main surveys, the temperature of the surface water at each station was recorded to the nearest tenth of a degree Centigrade. In addition, for Surveys 2, 3, and 4, a sample of the surface water at each station was taken and later analyzed for chlorinity (p.p.m.) by the Mohr method. The data are given in Table 1.

In the interim surveys, temperature, chlorinity, and oxygen determinations were made at three depths. The oxygen content (ml./l., adjusted to 20° C.) was determined by the Winkler method. The data are given in Table 2.

EXAMINATION OF PLANKTON SAMPLES

The plankton samples were examined under the binocular microscope by transferring the material, a small quantity at a time, to a Petri dish. Nehu eggs were removed and counted (Tables 3 and 4) according to three categories, "normal," "damaged," and "agglutinated," as defined below. Nehu larvae were removed, counted (Tables 5 and 6), and measured to the nearest tenth of a millimeter by means of a micrometer eyepiece. Standard length was defined as the distance from the tip of the snout to the end of the vertebral column (Table 12). Notes were made on the quantity of plankton in each bottle and on the relative abundance of the dominant organisms.

As the number of nehu eggs per sample was relatively small, the entire sample was examined rather than only a known fraction. This was a time-consuming procedure, usually requiring several man-hours per sample. Segregation of the nehu eggs and larvae was complicated by the presence of large numbers of chaetognaths and ctenophores which had to be teased apart. Despite this difficulty, it is believed that the counts include practically all nehu eggs and larvae in the samples.

Usually most of the eggs were "normal" in appearance—the developing embryo could be seen clearly and was surrounded by a transparent perivitelline space. In some, classed as "damaged," the inner membrane was ruptured and the yolk and shattered embryo had invaded the perivitelline space in varying degree. Obviously these had suffered mechanical injury during capture. In others, classed as

TABLE 1

SURFACE TEMPERATURE AND CHLORINITY IN KANEOHE BAY ACCORDING TO STATION AND SURVEY

STATION	TEMPERATURE (CENT.)				CHLORINITY (P.P.M.)		
	SURVEY 1	SURVEY 2	SURVEY 3	SURVEY 4	SURVEY 2	SURVEY 3	SURVEY 4
1	26.0	23.5	23.9	25.1	18.91	19.19	19.37
2	25.7	23.5	23.9	25.3	18.79	19.22	19.30
3	25.8	23.5	23.9	25.2	18.87	19.22	19.41
4	25.7	23.5	23.8	25.1	18.98	19.32	19.41
5	25.7	23.5	23.7	25.2	19.13	19.38	19.42
6	25.9	23.5	23.5	25.2	19.13	19.32	19.51
7	26.2	23.5	24.0	25.6	19.10	19.38	19.47
8	26.3	23.6	24.4	26.0	19.13	19.32	19.23
9	26.2	23.6	24.0	25.3	19.06	19.35	19.42
10	25.8	23.0	23.8	25.0	18.91	19.14	19.32
11	26.0	22.7	23.8	24.9	18.58	18.95	19.29
12	26.0	23.0	23.8	24.3	18.73	18.93	18.82
13	26.0	22.9	24.0	24.8	18.87	18.97	19.32
14	26.5	23.2	23.8	25.0	19.02	19.14	19.37
15	26.6	23.3	23.8	25.2	19.06	19.34	19.41
16	26.5	23.2	23.9	25.0	19.13	19.32	19.45
17	26.2	23.2	23.9	25.0	19.06	19.21	19.36
18	26.2	23.1	24.2	24.6	19.03	19.23	19.23
19	26.5	23.0	24.1	24.8	18.95	19.26	19.27
20	26.4	23.2	24.4	24.8	19.20	19.30	19.42
21	26.5	23.1	24.7	24.9	19.09	19.21	19.20
22	27.0	23.1	24.8	24.8	19.02	18.99	19.01
23	26.8	23.0	24.8	24.8	19.11	19.36	19.06
Mean	26.2	23.2	24.0	25.0	18.99	19.22	19.31

"agglutinated," disintegration of the yolk and embryo had occurred and the material filling the shell had a whitish color, as if decomposition had been under way for some time.

IDENTIFICATION OF EGGS AND LARVAE

Nehu eggs are oval in shape, bluntly ovoid at the ends, and about twice as long as wide. Measurements of 20 eggs from the hauls gave an average length of 1.36 mm. and an average width of 0.61 mm. The yolk contains no oil globule. The shape and size of nehu eggs readily distinguish them from most other round or slightly oval fish eggs found in the plankton. Absence of an oil globule distinguishes them from others of about the same size and shape which belong to an unknown species and which were found on one occasion in a tow taken outside of the bay by Dr. A. H. Banner.

TABLE 2

TEMPERATURE, CHLORINITY, AND OXYGEN ACCORDING TO DEPTH DURING SURVEYS 1*a* AND 1*b*

SURVEY	DEPTH	TEMPERATURE	CHLORINITY	OXYGEN
	feet	*centigrade*	*p.p.m.*	*ml./l.*
1*a*	2	23.7	19.29	5.00
	10	23.5	19.40	4.97
	20	23.4	19.33	5.00
1*b*	5	22.8	19.38	5.12
	20	22.6	19.48	5.18
	32	22.5	19.57	5.46

All nehu eggs taken in the tows were at about the same stage of development. The embryo extended approximately one-half to three-quarters of the distance around the yolk; somites were visible in some specimens; the head was taking shape around the lobes of the brain; and the developing eyes were visible but not conspicuous. Less advanced eggs in the blastodermal cap stage, and more advanced eggs closer to the hatching stage, were not encountered. It has since been found (Yamashita, MS.) that spawning takes place at night, mostly from about 10 P.M. to midnight, and that development from fertilization to hatching occurs in about 24 hours. This explains the rather uniform stage of development of the eggs, for in all tows they were taken during the same 5-hour period of the day—from about 9 A.M. to 2 P.M. Similar observations have been made by Delsman (1929) who pointed out that night spawning and rapid embryonic development are typical of tropical species of *Engraulis* and *Stolephorus* occurring in Javanese waters.

Nehu larvae have been hatched in small shallow dishes of sea water from eggs taken in plankton hauls (Yamashita, MS.). The newly hatched larvae, about 2 mm. in length, have a large, crescent-shaped yolk sac attached to the ventral surface of the body from head to vent. This is gradually absorbed until, at 36 hours after hatching, only a small round ball of yolk remains at the "throat." During these early stages the larvae may be recognized fairly readily by their size, the slender elongated body form, the shape and position of the yolk sac when present, the reticulated appearance of the myotomes, the origin of the dorsal fin fold at the posterior end of the head, and the position of the anus, which is from two-thirds to three-quarters of the distance along the body. At the more advanced stages, the chief diagnostic characters are the slender body form, the reticulated appearance

TABLE 3

NUMBER OF NEHU EGGS PER 10-MINUTE SURFACE HAUL WITH THE 100 CM. NET ACCORDING TO SURVEY, STATION, AND DIRECTION (A AND B), AND SUMMARY

STATION	SURVEY 1		SURVEY 2		SURVEY 3		SURVEY 4		MEAN PER CENT OF SURVEY TOTAL
	A	B	A	B	A	B	A	B	
1.......	–	–	–	–	–	–	5	11	0.16
2.......	–	–	–	–	–	15	–	3	0.07
3.......	233	314	21	107	89	347	6	29	5.12
4.......	1,930	956	383	490	4,180	4,781	127	296	48.63
5.......	769	116	419	332	38	2	262	259	18.41
6.......	30	10	3	3	1	–	3	2	0.28
7.......	2	–	3	2	–	–	8	2	0.17
8.......	–	1	–	–	–	–	53	27	0.82
9.......	6	3	3	2	23	149	123	17	1.97
10.......	–	2	7	2	8	4	–	–	0.15
11.......	–	1	7	5	1	–	–	–	0.16
12.......	3	5	3	0*	5	3	–	–	0.09
13.......	56	172	10	4	55	113	4	2	1.51
14.......	223	117	18	5	14	8	326	150	6.50
15.......	111	113	18	21	8	22	125	121	3.94
16.......	8	8	27	1	73	34	166	122	3.65
17.......	495	141	21	23	31	15	39	30	3.74
18.......	262	143	–	–	2	–	–	–	1.50
19.......	–	–	–	–	–	–	15	11	0.27
20.......	310	205	–	–	–	1	45	33	2.71
21.......	12	–	–	–	–	–	8	1	0.14
22.......	–	–	–	–	–	–	1	–	0.01
23.......	–	–	–	–	–	–	–	–	0.00
Totals....	4,450	2,307	943	997	4,528	5,494	1,316	1,116	100.00

* Part of haul lost.

TABLE 4

Number of Nehu Eggs per 10-Minute Surface Haul with the 22 cm. Net (Surveys 1, 3, and 4) or the 12.3 cm. Net (Survey 2), according to Survey, Station, and Direction (A and B), and Summary

STATION	SURVEY 1		SURVEY 2		SURVEY 3		SURVEY 4		MEAN PER CENT OF SURVEY TOTAL
	A	B	A	B	A	B	A	B	
1.......	–	–	–	–	–	–	1	–	0.17
2.......	–	–	–	–	–	1	–	–	0.04
3.......	37	83	3	6	6	22	–	2	7.02
4.......	244	193	7	26	217	279	11	15	46.14
5.......	130	15	27	20	5	–	13	17	21.52
6.......	2	1	–	–	–	–	–	–	0.07
7.......	–	–	–	–	–	–	1	–	0.17
8.......	1	–	–	–	–	–	4	3	1.19
9.......	6	7	1	–	–	14	10	1	3.05
10.......	–	–	1	1	–	–	–	–	0.54
11.......	–	–	–	–	–	–	–	–	0.00
12.......	1	5	–	–	1	–	–	–	0.20
13.......	4	28	–	–	–	10	–	–	1.25
14.......	26	9	–	–	–	–	20	6	5.22
15.......	12	19	–	–	1	1	5	6	2.70
16.......	1	–	–	–	1	3	9	7	2.87
17.......	72	18	–	1	3	2	6	4	4.43
18.......	29	8	–	–	–	–	–	–	0.93
19.......	1	–	–	–	–	–	–	1	0.19
20.......	22	16	–	–	–	–	2	5	2.13
21.......	–	–	–	–	–	–	1	–	0.17
22.......	–	–	–	–	–	–	–	–	0.00
23.......	–	–	–	–	–	–	–	–	0.00
Totals....	588	402	39	54	234	332	83	67	100.00

of the myotomes, the position of the anus, the projecting lower jaw (up to about 15 mm.), and the lateroventral position of the pectoral fins.

Many of the larvae taken in the tows were damaged to a varying extent. In young larvae the yolk was often torn from the yolk sac, and the fin fold was usually shredded. In older larvae part of the head, including the eyes, was often missing. This complicated the problem of identification. More serious, however, is the possibility that some nehu larvae, broken into fragments, were not recognized as such and were not included in the counts.

VARIABILITY OF THE DATA AND RELATIVE EFFICIENCY OF THE NETS

It will be recalled that, in sampling, two nets were hauled simultaneously, first in A direction and then in B direction at each station. Following the method of Winsor and Clarke (1940), the data may be used to investigate the components of variance and the relative efficiency of the nets. Analyses were made for the egg catches of each survey, using three criteria of classification—stations, haul order, and nets. To approximate normal distributions, the data were transformed to logarithms. The method of analysis is explained by Snedecor (1948: 11.14). Unfortunately, because of the small numbers taken, it was necessary to omit data from many of the stations. The stations included are as follows: Survey 1—3, 4, 5, 13, 14, 15, 17, 18, and 20; Survey 2—3, 4, and 5; Survey 3—3, 14, 16, and 17; and Survey 4—4, 5, 8, 9, 14, 15, 16, 17, and 20. The results are given in Table 7.

TABLE 5

NUMBER OF NEHU LARVAE PER 10-MINUTE SURFACE HAUL WITH THE 100 CM. NET ACCORDING TO SURVEY, STATION, AND DIRECTION (A AND B), AND SUMMARY

STATION	SURVEY 1		SURVEY 2		SURVEY 3		SURVEY 4		MEAN PER CENT OF SURVEY TOTAL
	A	B	A	B	A	B	A	B	
1.......	16	30	1	3	–	5	1	–	3.58
2.......	3	3	2	–	4	8	2	18	5.50
3.......	14	9	4	–	–	3	2	6	2.66
4.......	23	23	14	4	1	7	6	6	6.59
5.......	45	39	26	14	2	2	9	9	10.09
6.......	90	50	25	24	3	2	25	21	14.21
7.......	57	115	15	16	2	15	6	3	14.74
8.......	53	105	5	2	3	–	4	6	7.75
9.......	25	13	5	5	3	4	10	4	5.40
10.......	2	–	7	8	–	5	13	17	5.12
11.......	1	–	18	13	–	1	1	4	3.60
12.......	–	–	7	3*	–	1	4	4	1.81
13.......	–	–	5	1	3	–	3	3	1.91
14.......	2	–	3	2	–	2	43	28	6.14
15.......	–	–	6	1	–	–	33	20	4.38
16.......	–	–	–	2	–	2	6	7	1.72
17.......	3	–	5	–	–	–	13	13	2.40
18.......	1	–	2	4	–	1	1	2	1.10
19.......	–	–	3	2	–	–	1	1	0.61
20.......	–	–	–	–	–	1	–	1	0.38
21.......	–	–	–	–	–	–	–	–	–
22.......	–	–	–	–	–	–	–	–	–
23.......	–	–	–	–	–	1	–	–	0.31
Totals....	335	387	153	104	21	60	183	173	100.00

* Part of haul lost.

As there were obviously large differences in egg catches, both between stations and between nets, the large mean squares for stations and nets were expected. The mean square for haul order was relatively large in Surveys 1, 2, and 4, but includes a large S×H (station by haul) interaction component, and cannot be regarded as generally significant. Moreover, the (geometric) means for A and B hauls (converted from logarithms) do not show a consistent difference from survey to survey:

SURVEY	A	B
1..................	101.4	67.0
2..................	35.2	61.5
3..................	36.7	48.6
4..................	28.5	20.1

Greater interest is centered in the interactions. In all four surveys the S×H interaction is large, and in Surveys 1 and 4 it is highly significant. This demonstrates a lack of consistency in the relative catches of A and B hauls from station to station, due to causes other than chance variation. In all surveys, the S×N (station by net) interaction is relatively large, at least larger than the residual variance S×H×N, but in no case is it statistically significant. It probably includes a real component of variance, σ_{SN}^2, which is of small magnitude. For the present, however, it may be assumed that the catches of the two nets, apart from order of haul, bear a consistent ratio to each other from station to station. The H×N (haul order by net) interaction is small; in fact, it is smaller than the S×H×N interaction in all surveys except the third. In other words, for the same station the catches made in A and B order for each of the two nets are somewhat more consistent than might be expected on the basis of chance

TABLE 6

NUMBER OF NEHU LARVAE PER 10-MINUTE SURFACE HAUL WITH THE 22 CM. NET (SURVEYS 1, 3, AND 4) OR THE 12.3 CM. NET (SURVEY 2) ACCORDING TO SURVEY, STATION, AND DIRECTION (A AND B), AND SUMMARY

STATION	SURVEY 1		SURVEY 2		SURVEY 3		SURVEY 4		MEAN PER CENT OF SURVEY TOTAL*
	A	B	A	B	A	B	A	B	
1	3	–	–	–	–	–	–	–	1.51
2	–	–	–	–	–	–	–	–	–
3	1	–	1	1	–	–	1	–	7.72
4	4	12	–	–	–	–	–	–	8.08
5	3	9	1	2	–	1	–	1	15.84
6	8	4	–	2	–	–	4	2	23.69
7	–	3	2	1	–	–	–	–	9.21
8	4	4	–	–	–	–	–	–	4.04
9	8	1	–	–	–	–	1	–	6.63
10	–	–	1	–	–	–	–	–	2.56
11	–	–	1	–	–	–	–	–	2.56
12	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–
14	–	–	1	–	–	–	3	2	12.98
15	–	–	–	–	–	–	1	–	2.08
16	–	2	–	–	–	–	–	–	1.01
17	–	–	–	–	–	–	–	–	–
18	–	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	1	–	2.08
20	–	–	–	–	–	–	–	–	–
21	–	–	–	–	–	–	–	–	–
22	–	–	–	–	–	–	–	–	–
23	–	–	–	–	–	–	–	–	–
Totals	31	35	7	6	–	1	11	5	99.99

* Omitting Survey 3.

variation, i.e., nets towed simultaneously seem to yield partially correlated data.

Before presenting further data to assist in the interpretation of the significant S×H interaction, the relative efficiency of the nets will be considered. The (geometric) mean relative efficiency may be calculated from the logarithmic data. Thus, for Survey 1, the sum of the logarithms of the catches for the 100 cm. net (A and B hauls) is 42.8000, and for the 22 cm. net it is 26.2514. The difference, 16.5486, divided by the number of paired hauls, 18, is 0.9194. The catch ratio, 22 cm. net/100 cm. net, is the antilog of –0.9194 ($\bar{1}$.0806), or 0.1204.

Modifying the formula presented by Winsor and Clarke (1940), the standard error of the ratio involving two nets is given, in logarithms, by

$$\sqrt{\frac{1}{N}\cdot 2(\sigma_{SHN}^2+k_1\sigma_{HN}^2+k_2\sigma_{SN}^2)}$$

where N is the number of paired hauls, and k_1 and k_2 are the number of items associated with the respective variance components. In our data (except that of Survey 3), σHN^2 is considered to be 0, rather than a negative quantity. The variance components σSHN^2 and $k_2\sigma SN^2$ constitute the mean square for the S×N interaction. Thus for Survey 1, the standard error of the ratio, in logarithms, is

$$\sqrt{\frac{1}{18}\cdot 2(0.02157)} = 0.0490.$$

The confidence interval, mean ±2 s.e., may be calculated in logarithms and then converted, giving 0.0961 and 0.1509.

The following data have been calculated for each survey:

SURVEY	CATCH RATIO	CONFIDENCE INTERVAL	THEORETICAL CATCH RATIO
1.......	0.1204	0.0961–0.1509	0.0484
2.......	0.0558	0.0300–0.1037	0.0151
3.......	0.0614	0.0338–0.1115	0.0484
4.......	0.0688	0.0552–0.0874	0.0484

In the above tabulation, the theoretical ratios are those for the areas of the net mouths: 100 cm. net, 7,854.0 cm.^{2}; 22 cm. net, 380.13 cm.^{2}; 12.3 cm. net, 118.82 cm.^{2}.

The observed catch ratios differ significantly from the theoretical ratios for all surveys except the third. The smaller nets (22 cm. and 12.3 cm.) are relatively more efficient than the large net (100 cm.). This is in contrast to the results of Winsor and Clarke, although the data are not directly comparable as they were dealing with motile organisms. The exceptionally large ratio in Survey 1 is doubtless due mostly to loss of eggs from the 100 cm. net when small rips developed, as already explained. The reason for the larger-than-expected ratios in the other surveys is less clear: the straining area of the large net was relatively greater than that of the small nets; the apertures of the mesh in all nets were sufficiently small to retain the eggs, with the possible exception of that of the forward and middle parts of the large net. In these parts it is possible, although not likely, that eggs could have escaped in an end-on position. The efficiency of the large net may have been decreased by loss of plankton during transfer to containers, or by progressive clogging within days, as noted in a previous section.

TABLE 7

ANALYSIS OF VARIANCE OF EGG CATCHES IN SURVEYS 1 TO 4 ACCORDING TO STATIONS, HAUL ORDER, AND NETS

SURVEY	SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
1	Stations (S)................................	8	4.28258	0.53532
	Haul order (H)................................	1	0.27991	0.27991
	Nets (N)................................	1	7.60712	7.60712
	S×H................................	8	1.70812	0.21352**
	S×N................................	8	0.17259	0.02157
	H×N................................	1	0.00371	0.00371
	S×H×N................................	8	0.09480	0.01185
2	Stations................................	2	1.61393	0.80696
	Haul order................................	1	0.17610	0.17610
	Nets................................	1	4.71316	4.71316
	S×H................................	2	0.20601	0.10300
	S×N................................	2	0.10856	0.05428
	H×N................................	1	0.00006	0.00006
	S×H×N................................	2	0.09495	0.04748
3	Stations................................	3	11.85402	3.95134
	Haul order................................	1	0.05958	0.05958
	Nets................................	1	5.87432	5.87432
	S×H................................	3	0.34663	0.11554
	S×N................................	3	0.13537	0.04512
	H×N................................	1	0.05907	0.05907
	S×H×N................................	3	0.11017	0.03672
4	Stations................................	8	3.08473	0.38559
	Haul order................................	1	0.20672	0.20672
	Nets................................	1	12.15801	12.15801
	S×H................................	8	1.00648	0.12581**
	S×N................................	8	0.19387	0.02423
	H×N................................	1	0.00283	0.00283
	S×H×N................................	8	0.10926	0.01366

** Highly significant.

VARIATION IN CATCH WITH ORDER (DIRECTION) OF HAUL

Following Survey 1, Surveys 1*a* and 1*b* were undertaken to investigate in more detail the obviously large differences between A and B hauls at the same station, and also to study variation in egg and larva distribution with depth. To illustrate the differences between A and B hauls it might be noted from Tables 3 and 4 that at Station 4, the 100 cm. net caught 1,930 eggs in the A haul (one direction) and only 956 eggs in the B haul (opposite direction); similarly at the same station, the 22 cm. net took 244 eggs in the A haul and 193 eggs in the B haul. It is the lack of consistency in these differences from station to station which produces the large and significant S×H interaction demonstrated in the preceding section. The differences, which in many cases depart significantly from an expected difference of 0 (using a Chi-square test) may be due to differences in volume of water strained in A and B hauls, to non-random distribution of the eggs, or to both factors.

Surveys 1*a* and 1*b* were both undertaken in the vicinity of Station 4, which had yielded relatively large numbers of eggs in Survey 1. Each A and B haul was of exactly 10 minutes' duration. Two identical 22 cm. nets were towed simultaneously, one just below the surface and the other at a depth.

In Survey 1*a* an attempt was made to run four replicate hauls (I to IV), each replicate including an A and a B haul, and each haul including two depths, thus yielding 16 samples. Each A haul was in a southwesterly direction, with the wind, whereas each B haul was in a northeasterly direction, against the wind. The distance travelled in A hauls, about 3,000 feet, was greater than in B hauls, about 2,400 feet, due to the greater speed attained when travelling with the wind. In the A hauls it was necessary to diverge from the usual Station 4 course to miss the reefs off the southeast side of Coconut Island. Before starting the B hauls, the ship was run along the east shore of the island in order to assume the usual Station 4 course, as illustrated in Figure 2. The resulting data are shown in Table 8, and the analysis of the data, after transformation to logarithms, is shown in Table 9. In the latter, the data were adjusted to an average distance of 2,700 feet in an attempt to overcome one source of variation. This would correct for differences in volume of water strained in A and B hauls only if there were no change in the efficiency of the nets with change in speed.

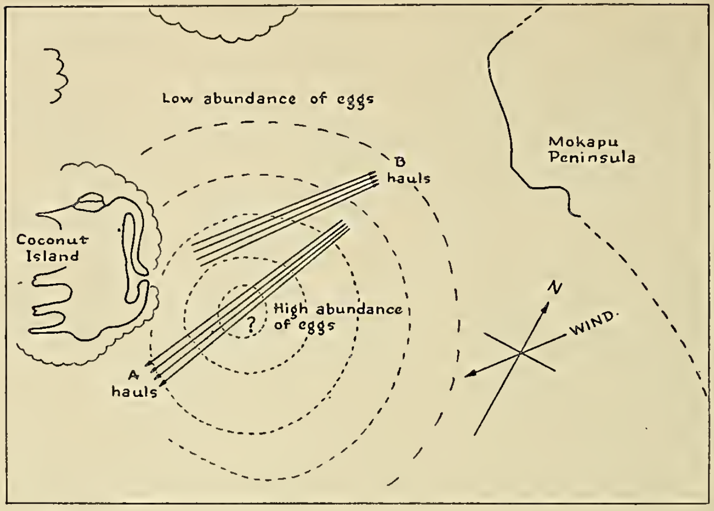

FIG. 2. A portion of the southern sector of Kaneohe Bay in the vicinity of Stations 4 and 5, showing the location of A and B hauls in Survey 1*a*, and indicating the presumed distribution of the eggs (broken isolines).

The adjusted egg catches are as follows:

REPLICATES	A		B	
	surface	*deep*	*surface*	*deep*
I........	148	130	79	37
II........	520	456	29	35
III........	323	302	106	64
IV........	306	254	56	46

As shown by the analysis (Table 9), there are no significant differences between the (geometric) mean catches for replicates (87, 125, 160, and 119, respectively). However, there is a highly significant difference between the means for haul order or direction (A, 277; B, 52), despite the correction for distance travelled. It is most unlikely that this is due to a change in net efficiency with speed, as the A hauls, at the faster speed, had the higher mean counts; efficiency would be expected to decrease with increase in speed. The analysis also shows a significant R×H

TABLE 8

NUMBER OF EGGS AND LARVAE ACCORDING TO HAUL ORDER (DIRECTION), AND DEPTH FOR SURVEY 1*a* IN THE VICINITY OF STATION 4

HAUL	DEPTH OF TOW		NUMBER OF EGGS		NUMBER OF LARVAE	
	SURFACE	DEEP	SURFACE	DEEP	SURFACE	DEEP
	feet	*feet*				
IA..............	1	6	165	144	–	1
IB..............	2	10	70	33	–	3
IIA..............	1	6	578	507	1	1
IIB..............	2	10	26	31	–	1
IIIA..............	1	10	359	336	–	1
IIIB..............	2	17	94	57	–	1
IVA..............	1	10	340	282	1	1
IVB..............	2	17	50	41	1	4
Totals..............			1,682	1,431	3	13

(replicate by haul order) interaction, i.e., variation other than that due to chance in the differences between A and B catches from replicate to replicate. Both the difference between the catches in A and B hauls and the large R×H interaction can be most plausibly attributed to non-random horizontal distribution of the eggs, as will be explained later.

In Survey 1*b* an attempt was made to cover the area in the vicinity of Stations 4 and 5 in a grid formation with one series of three substation hauls (I to III) spaced at intervals and following a general east-west direction, and a second series of three substation hauls (IV to VI) also spaced at intervals but following a general north-south direction. Each substation was represented by an A and a B haul, and each haul included a surface and a deep sample. In the first series, the A hauls were easterly, against the wind, and the B hauls were westerly, with the wind. In the second series, the A hauls were southerly and the B hauls were northerly, both crosswise to the wind, as illustrated in Figure 3. Deviations from a rectangular grid pattern were necessary because of danger of snagging the deep net on intervening shallows. On one occasion (Haul IIA) the deep net struck the bottom and was torn; it was replaced by another identical net in later hauls. No adjustment was made to compensate for loss of plankton in this haul, but the error introduced will not materially affect the conclusions of either this section or the one which follows. It was estimated that the ship travelled 2,400 feet during A hauls and 3,000 feet during B hauls in the first series, and that it travelled 2,700 feet in both A and B hauls in the second series. The data for each of the 24 samples are given in Table 10, and the analysis of the data, after adjustment to a mean distance of 2,700 feet and transformation to logarithms, is given in Table 11.

The adjusted egg catches are as follows:

SERIES	SUB-STATIONS	A		B	
		surface	*deep*	*surface*	*deep*
1	I	89	69	88	84
	II	21	6	46	44
	III	3	2	17	23
2	IV	191	133	146	124
	V	120	84	141	97
	VI	58	52	53	51

TABLE 9

ANALYSIS OF VARIANCE OF EGG CATCHES IN SURVEY 1*a* ACCORDING TO REPLICATE DOUBLE HAULS, HAUL ORDER (DIRECTION), AND DEPTH

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Replicates (R)	3	0.14504	0.04835
Haul order (H)	1	2.11768	2.11768**
Depth (D)	1	0.03796	0.03796
R×H	3	0.33144	0.11048*
R×D	3	0.02159	0.00720
H×D	1	0.00669	0.00669
R×H×D	3	0.02470	0.00823

* Significant.

** Highly significant.

TABLE 10

NUMBER OF EGGS AND LARVAE ACCORDING TO HAUL ORDER, AND DEPTH FOR SURVEY 1*b* IN THE VICINITY OF STATION 4

HAUL	DEPTH OF TOW		NUMBER OF EGGS		NUMBER OF LARVAE	
	SURFACE	DEEP	SURFACE	DEEP	SURFACE	DEEP
	feet	*feet*				
IA..............	2	19	79	61	1	1
IB..............	1	16	98	93	1	1
IIA..............	2	19*	19	5*	–	–
IIB..............	1	16	51	49	3	4
IIIA..............	2	20	3	2	1	2
IIIB..............	1	17	19	26	4	4
IVA..............	1	17	191	133	–	–
IVB..............	1	16	146	124	–	1
VA..............	1	17	120	84	–	1
VB..............	2	18	141	97	–	1
VIA..............	2	17	58	52	6	1
VIB..............	2	18	53	51	2	1
Totals....................................			978	777	18	17

* Net hit bottom; some damage to net and loss of plankton.

As shown by the analysis of the data (Table 11), there are significant differences between substations, which are due mostly to the large difference between series. The difference between the (geometric) means for haul order (A, 35; B, 63) is not significant: in Series 1 the means differed to some extent (A, 13; B, 42), whereas in Series 2 they were similar (A, 96; B, 94). However, there is a significant interaction, now designated as S×H (substations by hauls), showing lack of consistency in the differences between A and B hauls from substation to substation. Again, the results may be most plausibly explained on the basis of non-random horizontal distribution of the eggs.

TABLE 11

ANALYSIS OF VARIANCE OF EGG CATCHES IN SURVEY 1*b* ACCORDING TO SERIES, SUBSTATIONS, HAUL ORDER, AND DEPTH

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Substations (S)	5	4.91036	0.98207*
Between series	1	2.60827	2.60827
Within series	4	2.30209	0.57552
Haul order (H)	1	0.38457	0.38457
Depth (D)	1	0.07549	0.07549*
S×H	5	0.81374	0.16275**
S×D	5	0.04786	0.00957
H×D	1	0.04437	0.04437
S×H×D	5	0.05212	0.01042

* Significant.

** Highly significant.

To explain the foregoing results satisfactorily it is necessary to assume only that there is a focus of abundance of eggs in the vicinity of Station 4, with gradients of decreasing abundance extending outward in all directions. The nature of the egg distribution which is postulated to have occurred during Surveys 1*a* and 1*b* is illustrated in Figures 2 and 3. Transection of the area at various distances from the focus would cause the great variability in catch and would readily account for the observed significant differences and interactions. As will be shown later, the presence of a focus of abundance of eggs in the vicinity of Station 4 is also demonstrated by the results of the general surveys.

It seems likely that non-random distribution of the eggs occurs at all stations. Slightly different gradients of abundance are passed through in making A as compared with B hauls, often causing large differences in the number of eggs caught. A similar situation may also occur in the case of larvae, although the differences between A and B hauls are, in general, less pronounced and persistent. Be-

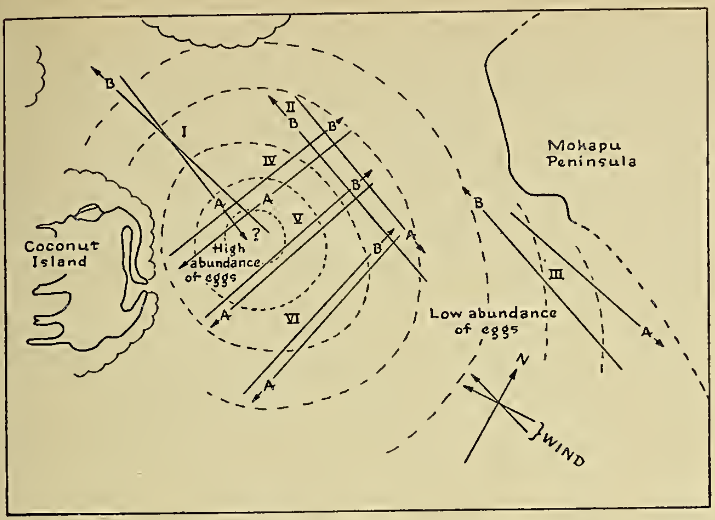

FIG. 3. A portion of the southern sector of Kaneohe Bay in the vicinity of Stations 4 and 5, showing the location of A and B hauls in Survey 1*b*, and indicating the presumed distribution of the eggs (broken isolines).

cause of the small numbers of larvae taken in the samples, a similar detailed analysis of the data was not undertaken.

Obviously, the peculiar non-random distribution of the eggs should be taken into consideration in designing a program of quantitative sampling for future work.

VERTICAL DISTRIBUTION OF EGGS AND LARVAE

The vertical distribution of eggs and larvae was studied only at Station 4 during Surveys 1*a* and 1*b*, the details of which have been discussed in the previous section. Unfortunately, it was not possible to sample efficiently over a range of depth. In analyzing the results (Tables 9 and 11), the surface samples, from 1 to 2 feet, are compared with those at "a depth," the depth ranging from 6 to 17 feet in Survey 1*a* (Table 8) and from 16 to 20 feet in Survey 1*b* (Table 10). The (geometric) mean catches of eggs in the adjusted data may be compared in the following tabulation:

HAULS	SURVEY 1*a*	SURVEY 1*b*
Surface	134	54
Deep	107	41

In both surveys there were more eggs at the surface than at a depth. There were no significant interactions involving depth in either Survey 1*a* (R×D and H×D) or Survey 1*b* (S×D and H×D). The significance of the difference between surface and deep hauls was tested by comparing the mean square for depth with an error term derived by pooling the sums of squares and degrees of freedom for the last three components in each of Tables 9 and 11. The difference approached significance for Survey 1*a* and was significant (P less than 0.05) for Survey 1*b*. It may be concluded that there are slightly more eggs at the surface than at a depth. It seems likely that there is a gradient of decreasing abundance from surface to bottom, although this cannot be affirmed positively from the present data.

The variation of temperature, chlorinity, and oxygen with depth for Surveys 1*a* and 1*b* is shown in Table 2. The results for Survey 1*b*, in particular, suggest that there may be a relationship between the vertical distribution of the eggs and the vertical distribution of these physical factors. Temperature decreases with depth, whereas both chlorinity and oxygen increase with depth. At the present stage of investigation it is idle to speculate as to the nature of the possible relationship.

The numbers of larvae taken in the various hauls of Surveys 1*a* and 1*b* were small. In 1*a*, fewer larvae were caught at the surface than at a depth, whereas in 1*b*, slightly more were caught at the surface than at a depth. No significant change in larva distribution with depth can be demonstrated with the present data.

HORIZONTAL DISTRIBUTION OF EGGS AND LARVAE

It has been shown that there are highly significant differences between the catches of eggs made from station to station, apart from differences between hauls at the same station. Accordingly, in the gross analysis to follow, the count at each station is assumed to be representative of a particular abundance level at each station.

Distribution of Eggs

To show the general distribution of eggs throughout the bay, the number (A plus B hauls) taken at each station was expressed as a percentage of the total number caught in each survey, and the four percentages for each station were averaged. This gave the data in the last column of Tables 3 and 4. The results for the 100 cm. net are portrayed graphically in Figure 4.

The following tabulation shows the general distribution of eggs according to sector and net:

SECTOR	LARGE NET		SMALL NETS	
	per cent of total	*mean per cent per station*	*per cent of total*	*mean per cent per station*
Southern	75.63	8.40	79.37	8.82
Middle	19.74	2.47	17.21	2.15
Northern	4.63	0.77	3.42	0.57

The results show that eggs were most abundant in the southern sector, less abundant in the middle sector, and least abundant in the northern sector. The results for Surveys 1, 2, and 3 were fairly consistent with the above averages. In Survey 4, however, most eggs were found in the middle sector.

Examination of the temperature and chlorinity data of Table 1 shows no apparent correspondence between their distribution and that of the eggs. For example, the average temperature (four surveys) for the three sectors were respectively 24.7, 24.5, and 24.7°C.; the average chlorinities (three surveys) for the three sectors were respectively 19.23, 19.11, and 19.16 p.p.m.

In the southern sector of the bay, all four surveys showed a peak of abundance of eggs in the vicinity of Stations 4 or 5 (Fig. 4, Tables 3 and 4). Both the interim surveys and casual sampling between surveys indicated the persistence of this peculiar distribution. There is no apparent relationship between the distribution of eggs (Table 3) and the distribution of temperatures and chlorinities in the southern sector (Table 1). The explanation of the focus of abundance of eggs in the northeast part of the southern sector is uncertain. It seems most likely that the eggs are held there in the eddy of a current, but information on this possibility must await a study of the circulation of water in the bay. If it is found that the eggs are held in an eddy system, it must still be discovered whether nehu eggs are accumulated from widespread spawning throughout the sector or whether they result from localized spawning near the center of the eddy.

In the middle sector of the bay, all four surveys showed larger numbers of eggs in the more northerly part, Stations 13 to 17, than in the more southerly part, Stations 10 to 12 (Fig. 4, Tables 3 and 4). Although on the average the maximum concentration was at Station 14, the peak of abundance varied from station to station with survey. For example, the largest number of eggs was encountered at Station 17 in Surveys 1 and 2, at Station 13 in Survey 3, and at Station 14 in Survey 4. This is in contrast to the relatively stable condition found in the southern sector of the bay. Variation in abundance at a station from survey to survey may be related to variation in the number of spawning fish, to variation in the current system in the middle sector, or to both factors. Judging from the topography of the middle sector, the current system would probably vary to a considerable extent with strength and direction of the wind and with phase of the tide.

In the northern sector of the bay, eggs were encountered in fair numbers only during Surveys 1 and 4. In Survey 1 they were relatively abundant at Stations 20 and 18, and in Survey 4, at Stations 20 and 19. On the average, the greatest abundance was at Station 20, which is located in the main ship channel toward the outside reefs. Either no eggs or very few eggs were taken at Stations 21, 22, and 23, which are located among the shoreside reefs in the northernmost part of the bay.

Comparison of Table 1 with Tables 3 and 4 shows no apparent relationship between variation in temperature and chlorinity and variation in egg abundance from station to station within surveys for either the middle or northern sectors of the bay.

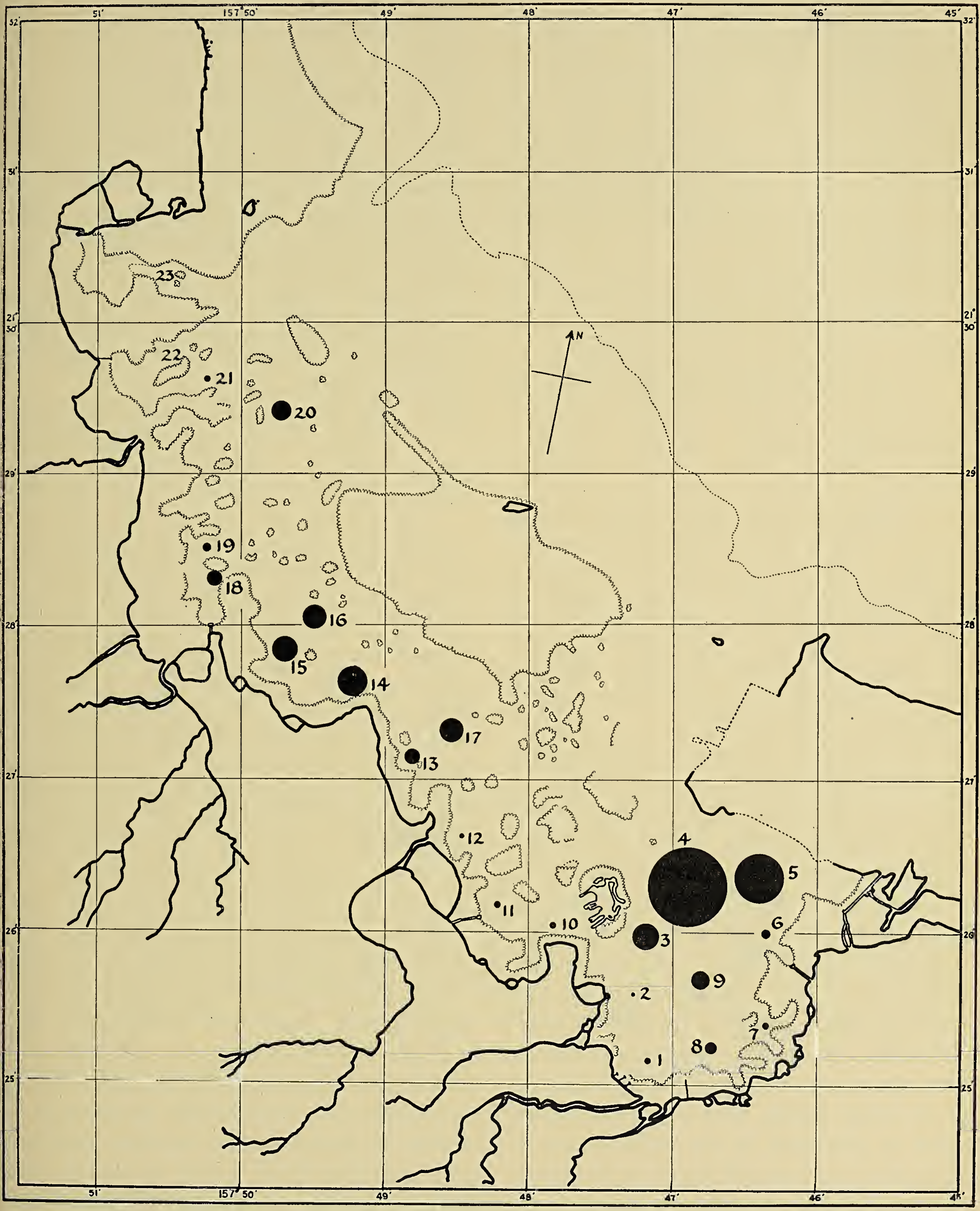

FIG. 4. Map of Kaneohe Bay showing the general distribution of the eggs according to station. The black circles are proportional in area to the number of eggs taken in combined A and B hauls with the 100 cm. net at each station. The distribution is presumed to be continuous between stations, rather than discrete, as shown.

Distribution of Larvae

In considering variation in numbers of larvae with station and survey, data obtained with the 100 cm. net (Table 5) are more informative than those obtained with the smaller nets (Table 6) because of the larger numbers of larvae captured. The results for the 100 cm. net (A plus B hauls), expressed as an average percentage (Table 5), are shown graphically in Figure 5.

The general distribution of larvae according to sector and net is as follows:

SECTOR	LARGE NET		SMALL NETS	
	per cent of total	*mean per cent per station*	*per cent of total*	*mean per cent per station*
Southern	70.52	7.84	76.72	8.52
Middle	27.08	3.38	21.19	2.65
Northern	2.40	0.40	2.08	0.35

The general distribution of larvae is similar to that of the eggs in that they are most abundant in the southern sector, less abundant in the middle sector, and least abundant in the northern sector of the bay. As in the case of eggs, the results are fairly consistent except in Survey 4, when the abundance was greatest in the middle sector.

In the southern sector, the larvae are distributed from station to station in a manner which is conspicuously different from that of the eggs (compare Figs. 4 and 5, or Tables 3 and 5). While not randomly distributed, the larvae are more widely scattered than the eggs. Moreover, they appear to form a peak of abundance at Station 6 or 7 in the southern part of the sector rather than at Station 4 or 5 in the northern part. This peculiar distribution is fairly consistent from survey to survey. Again, the cause is obscure. While larvae are able to swim feebly, they must still be regarded as plankton in the early stages of development and are still largely at the mercy of the currents. A possible explanation will be advanced in a later section which deals with the length composition of the larvae.

In the middle sector of the bay, the larvae again seem to be more widely scattered than the eggs. On the average they were most abundant at Station 14, but this was not consistent from survey to survey. They were most abundant at Station 17 in Survey 1, at Station 11 in Survey 2, at Station 10 in Survey 3, and at Station 14 in Survey 4.

In the northern sector, the larvae were taken in small numbers at Stations 18, 19, and 20 and, on one occasion, at Station 23. It will be recalled that eggs were not taken at Station 23 in any of the four surveys.

Variation with Season

The total numbers of eggs and larvae taken in the 100 cm. net at all stations of each survey are as follows:

STAGE	SURVEY 1	SURVEY 2	SURVEY 3	SURVEY 4
	Sept.	*Dec.*	*March*	*June*
Eggs	6,757	1,940	10,022	2,432
Larvae	722	267	81	356

From the lack of consistent variation in the numbers of eggs and larvae taken from survey to survey, it is at once apparent that no conclusions can be drawn as to whether spawning is more intensive at one period of the year than at another. Certainly it would seem that spawning takes place throughout the year as found by Delsman (1931) for other species of *Stolephorus* in tropical waters, but information on seasonal variation must await a program of quantitative sampling at closer intervals of time.

MORTALITY OF EGGS

As mentioned previously, the eggs were segregated into three categories at the time of counting—"normal," "damaged," and "agglutinated." On the average, the percentages of eggs falling into the three categories were respectively 75, 20, and 5. However, there was considerable variation from station to station within surveys, and very great variation from survey to survey, particularly in the percentages of normal and damaged eggs. For example, in Survey 3 normal eggs accounted for 40.5 per cent and damaged eggs 58.2 per cent, whereas in Survey 4, normal eggs accounted for 85.5 per cent and damaged eggs 8.8 per cent. The

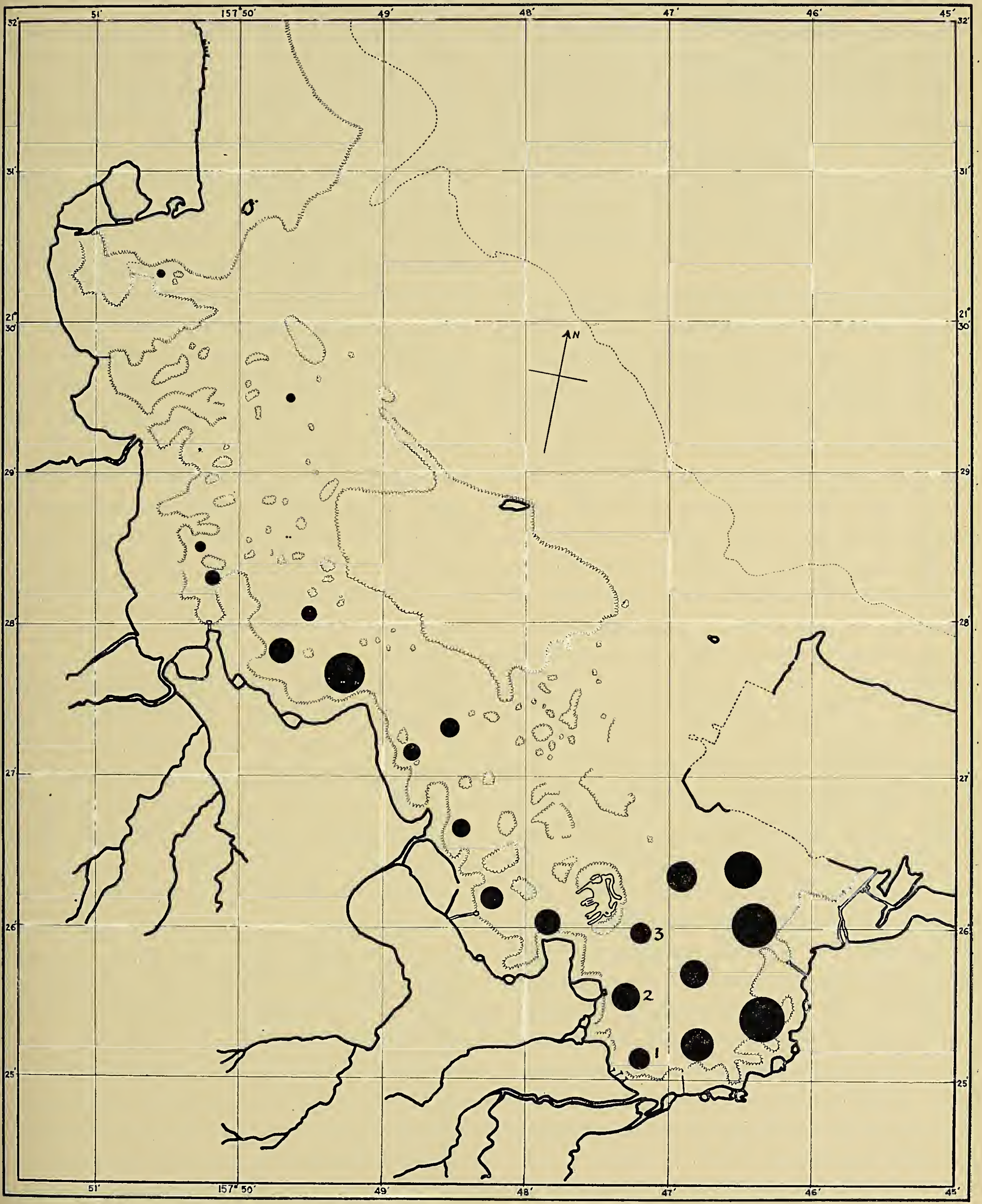

FIG. 5. Map of Kaneohe Bay showing the general distribution of the larvae. The black circles are proportional in area to the number of larvae taken in combined A and B hauls with the 100 cm. net at each station. The distribution is presumed to be continuous between stations, rather than discrete, as shown.

differences between surveys are probably related, in part at least, to differences in speed of tow. The average speed, as determined by readings of the Clarke-Bumpus current meter which was towed behind the boat in these two surveys, was 1.3 times as great in Survey 3 as in Survey 4. A high percentage of damaged eggs was also found in the two interim surveys when, in towing two small nets, the ship travelled faster than in towing a large and a small net.

The percentage of agglutinated eggs, while ranging from 1.3 in Survey 3 to 11.0 in Survey 2, did not seem to vary directly with speed of tow. Although the results are admittedly subject to some degree of error in distinguishing damaged from agglutinated eggs, they suggest that about 5 per cent of the eggs were dead at the time of capture. The only other possibility is that they were damaged on capture at the start of the tow and that decomposition proceeded with sufficient rapidity to reduce them to the agglutinated condition in 10 minutes or less. This seems unlikely.

If the agglutinated eggs are assumed to have been dead at the time of capture, the question arises as to the reason for their death. Some may have been regurgitated by chaetognaths and ctenophores, which were found to feed on the eggs. Others may have died "naturally" because of infertility, lack of vitality, or some other intangible factor. In this regard, D. Yamashita (unpublished) has observed that when normal undamaged eggs are kept in Petri dishes, a small percentage will die for no apparent reason. Determination of the cause and extent of the egg mortality would be of considerable interest and importance in the study of the dynamics of the nehu population.

LENGTH DISTRIBUTION OF LARVAE

The length distribution of larvae taken by both large and small nets is given for each survey in Table 12. It will be observed that the length ranges from 2.5 to 12 mm. Only one individual of larger size (20.5 mm.) was caught. The smallest nehu taken in the seines or night-light nets of the commercial fishermen are about 23 mm. These are post-larval fish which have not yet completely metamorphosed. It is clear, then, that the plankton nets did not sample the larva population completely. It seems reasonable to assume that the larger individuals escaped the net by virtue of their keener vision and greater swimming power, or these coupled with the adoption of the schooling habit.

The average length of the larvae varies significantly from survey to survey; for Surveys 1 to 4, the average lengths are 4.99, 5.73, 5.01, and 3.44 mm., respectively. The differences between surveys are probably related to variation from day to day in the extent of spawning, presuming that several day groups are represented in the length distribution. Although the data for comparing sectors within surveys are scanty, there seems to be a general similarity in the length distributions.

The percentage frequency distribution was calculated for each survey and the resulting four percentages for each length group were averaged, giving the data of the last column of Table 12. The length frequency polygon, shown in Figure 6, is obviously multimodal,

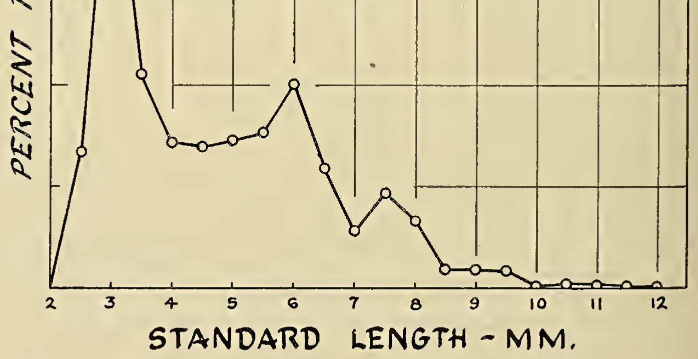

FIG. 6. The per cent frequency distribution of larvae according to length, all data combined.

TABLE 12

FREQUENCY DISTRIBUTION OF LARVAE TAKEN BY ALL NETS ACCORDING TO LENGTH, SURVEY, AND SECTOR (S, SOUTHERN; M, MIDDLE; N, NORTHERN), AND SUMMARY

LENGTH CLASS	SURVEY 1			SURVEY 2			SURVEY 3			SURVEY 4			MEAN PER CENT OF SURVEY TOTAL
	S	M	N	S	M	N	S	M	N	S	M	N	
2.5	27	–	–	–	–	–	8	–	–	28	26	1	7.12
3.0	178	6	1	6	2	–	11	3	–	54	123	4	23.35
3.5	63	–	–	21	4	–	3	2	–	19	43	2	10.27
4.0	57	–	–	10	9	–	–	2	2	11	9	–	7.29
4.5	54	–	–	23	3	4	5	–	–	13	4	–	6.24
5.0	61	1	–	27	5	–	3	1	–	6	2	–	6.81
5.5	73	–	–	20	11	2	3	1	2	3	3	–	7.44
6.0	56	–	–	25	8	2	9	5	–	6	1	–	10.03
6.5	50	–	–	14	12	1	6	–	–	3	1	–	6.33
7.0	41	–	–	5	6	–	1	–	–	3	1	–	2.94
7.5	43	–	–	6	8	2	6	–	–	2	2	–	5.07
8.0	30	1	–	7	6	–	4	–	–	–	1	–	3.56
8.5	9	–	–	2	2	–	1	–	–	–	–	–	0.98
9.0	14	1	–	3	2	–	–	–	–	–	–	–	0.95
9.5	4	1	–	4	1	–	1	–	-	–	–	–	0.95
10.0	3	–	–	–	–	–	–	–	–	–	–	–	0.10
10.5	–	–	–	2	–	–	–	–	–	–	–	–	0.19
11.0	1	–	–	1	–	–	–	–	–	–	1	–	0.19
11.5	1	–	–	–	–	–	–	–	–	–	–	–	0.03
12.0	2	–	–	–	–	–	–	–	–	–	–	–	0.06
–	–	–	–	–	–	–	–	–	–	–	–	–	–
20.5	–	–	–	–	1	–	–	–	–	–	–	–	0.09
Totals*	767	10	1	176	80	11	61	14	3	148	217	7	99.99

* The totals do not agree with those of other tables as some larvae were damaged and could not be measured.

with modes at 3.0, 6.0, 7.5, and possibly 9.0 mm.

In attempting to interpret the biological significance of the modes, it must be remembered that the eggs hatch between 12 midnight and 2 A.M. and that the newly hatched larvae are about 2.0 mm. in length. Since the tows were taken between 9 A.M. and 2 P.M., it seems reasonable to assume that the first mode, at 3.0 mm., includes larvae which are about 9 to 14 hours of age, comprising the 0-day group. Only a few of these, however, had the large yolk sac characteristic of larvae of this age reared in dishes. Some had obviously lost the yolk material when damaged during capture. Others, of 3.0 mm. and larger, appeared to have absorbed the yolk sac almost completely and to have advanced in their general development to a stage 24 hours older, at which the mouth parts are forming. It seems likely, therefore, that the distribution represented by the first mode includes larvae of both the 0-day group (9 to 14 hours) and also the 1-day group (33 to 38 hours).

Once the mouth has formed and the larvae start feeding, more rapid growth might be expected. Thus the modes at 6.0, 7.5, and 9.0 mm. may represent the 2-, 3-, and 4-day groups. This would indicate an absolute growth rate of 1.5 mm. per day. If this rate were maintained, the nehu would become initially vulnerable to the commercial fishery (at a length of about 23 mm.) within about 2 weeks after hatching. If there were a deceleration of growth (which is likely), it may still be assumed that the period between hatching and recruitment is short—a matter of weeks, rather than years as in most temperate zone fishes. The interpretation of the above results is, of course, tentative. More satisfactory data would be provided by a series of collections on successive days at the same stations.

To investigate the length frequency distribution of the larvae in the southern sector in more detail, the number in each length category for each station was expressed as a percentage of the total number caught in each survey. The four percentages for each length group at each station were then averaged. This method of calculation weights the percentages for each station according to the numbers caught at that station within surveys, but gives equal weight to the numbers caught during each survey. The results are shown in Figure 7.

As might be expected when the data are subdivided, the positions of the modes are somewhat erratic. An extra mode, which may represent the 1-day group, occurs at 4.5 mm. in some cases. In general, the smaller and younger larvae are relatively more abundant at Stations 6, 5, and 4 than elsewhere. Larger and older larvae are particularly abundant at Station 7, which is located behind the reefs at the southeast end of the bay. The results suggest that the newly hatched larvae are at first concentrated in the same area as the eggs, Stations 4 and 5, but that as they become larger and older they disperse from this area, with a large number moving in a clockwise direction through Station 6. The mechanism accounting for the peculiar distribution of larvae in respect to both number and length should be investigated.

Examination of the length distribution of the larvae in the middle sector reveals a somewhat similar situation. In general, the larvae at the centers of egg abundance, Stations 13 to 17, are smaller than those away from the centers, Stations 10 to 12. For example, the average length of the larvae in the former was 3.5 mm. whereas in the latter it was 5.3 mm. Again, this indicates a dispersal of the larvae from the areas of spawning.

In the northern sector only a few larvae were taken. Their average length was 4.6 mm.

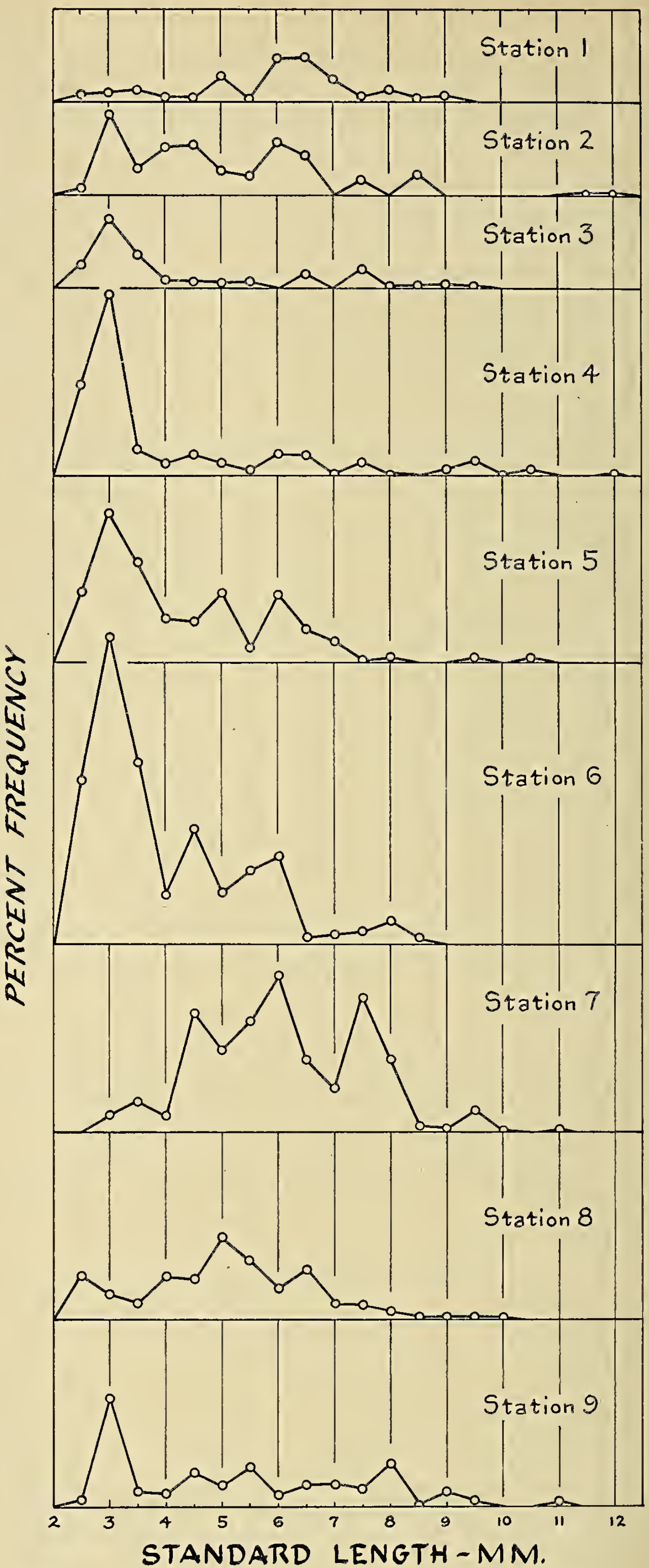

FIG. 7. The per cent frequency distribution of larvae according to length for each station in the southern sector of the bay.

An alternate explanation for the peculiar distribution of larvae in numbers and lengths might be advanced for both the southern and middle sectors. It might be postulated that both eggs and larvae remain close to the scene of spawning, and that the differences between stations are due primarily to erratic spawning at a station from day to day. This possibility cannot be denied, but such evidence as is presently available lends support to the interpretation given previously.

DISCUSSION

One of the objects of the present investigation was to formulate a sampling program for the estimation of egg and larva production throughout the year. Therefore it is in order to consider the design of such a program in the light of the present results. Its scope, however, must be limited by available funds.

The 100 cm. net is too large to be handled conveniently from a small vessel. The 22 cm. net is too small to give numbers of eggs and, particularly, larvae of sufficient magnitude for precise statistical analysis in a haul of reasonable time duration. Therefore a net of intermediate size, perhaps 50 cm. mouth diameter, is recommended. The net should be constructed of No. 40 grit gauze, and should be equipped with a current or flow meter and a detachable cod end. In design, it might follow that of the Hensen egg net.

Because of the small variability between catches of nets hauled simultaneously and the large variability between individual hauls, it would be more efficient to make several hauls with one net than to make one haul with several nets. For the same amount of work (chiefly involved in sorting plankton) four short hauls at one station, each of 5 minutes' duration, each spaced in regular fashion about the station, and each following a close, circular course, would be more informative than the sampling design followed in the present investigation.

Because of the slight but apparently consistent difference in egg abundance between surface and deep samples, horizontal tows at the surface, rather than either simultaneous surface and deep tows or oblique tows, could be used. However, the vertical distribution of the eggs should be subject to further investigation to determine the nature of the abundance gradient and its variation in time and space.

For a study of variation in abundance of eggs in the southern sector, one station located in the vicinity of Station 4 might suffice, provided it were sampled according to the above plan. Samples should be taken at close intervals of time throughout the year, say two per week. With a program such as this it should be possible to obtain information on both short-term and long-term fluctuations in the abundance of eggs. If the horizontal and vertical gradients of abundance, and their variation, could be established with precision, it should be possible to calculate the absolute abundance of eggs with reasonable accuracy. Interpolation in time and integration of the results would then lead to an estimate of total egg production for the southern sector which, according to this preliminary work, includes about 75 per cent of the total eggs spawned in Kaneohe Bay.

The sampling of eggs in the middle sector of the bay presents greater difficulty because of the lack of consistent variation from station to station with time. At least two, and preferably more than two stations should be included. With limited funds, it would be more efficient to make fewer hauls per station and to include more stations. A possible compromise might be to make two hauls at each of Stations 14 to 17 once a week.

Sampling for eggs in the northern sector might be neglected without any great loss of information, for the eggs occurring there form only about 4 per cent of the total. However, if included, it might be sampled at Station 20, two hauls, once a week.

If carried out as outlined, the above program would produce 936 samples per year. In addition, it would be desirable to check horizontal distribution at all stations and vertical distribution at certain key stations, e.g., Stations 4 and 16, at least at quarterly intervals, thus producing an additional two to three hundred samples. The total, about 1,200 samples, is regarded as the minimal number necessary for a reasonably accurate estimate of the production of nehu eggs in Kaneohe Bay.

The above program would provide data on variation in the abundance of eggs and, therefore, on variation in the abundance of the sexually mature portion of the fishable stock. Coupled with information on mortality and catch, it could lead to predictions of abundance of the mature population at various levels of fishing effort.

Estimation of larva abundance from plankton hauls is more difficult because of the widespread but non-random distribution of the larvae and their increased ability to escape the net as they become larger. Special stations for the estimation of larva abundance might be established, e.g., Station 7 in the southern sector, but this would greatly increase the number of samples to be collected and sorted. It might be possible to measure the abundance of larvae more accurately and with less effort by another method of collection—quantitative night-light traps. This possibility is now under investigation.

The reasons for the peculiar distribution of eggs and larvae in Kaneohe Bay are unknown, although presumably the distribution is related to the prevailing current pattern. A hydrographic study of the current system in all sectors of the bay at various times of year and under various weather and tide conditions is highly desirable.

The investigation was confined to the waters within Kaneohe Bay. There is the possibility that nehu eggs may also occur in coastal and offshore waters outside the bay. The presence of anchovy eggs in offshore waters has been reported for other species, e.g., the Australian anchovy, *Engraulis australis*, investigated by Blackburn (1941), the California or Northern anchovy, *Engraulis mordax*, investigated by Marr and Ahlstrom (1948), and several species of *Engraulis* occurring along the coast of Java and Sumatra, investigated by Delsman (1929). Furthermore, the eggs of several species of *Stolephorus* were also found offshore by Delsman (1931) in the last-named tropical locality. On the other hand, our local anchovy, the nehu, does not characteristically occur in the open ocean. As pointed out by Tester and Hiatt (in press), it appears to be confined to the bays and inlets where the water is somewhat more turbid and less saline than that of the open sea. As far as can be determined, nehu eggs have not yet been recovered from offshore waters adjacent to Hawaii by other agencies in the Territory who have made plankton hauls for pelagic fish eggs. Although it seems likely that nehu eggs do not occur extensively in offshore waters, the possibility that they are carried to or spawned in the open sea should be investigated.

The early life history of the nehu appears to be similar to that of the tropical anchovies studied by Delsman (1929 and 1931). In both, spawning takes place throughout the year, spawning occurs at night, there is a rapid embryonic development with an incubation period of 24 hours or less, and there is rapid growth during the larval stages. Two general features—continuous spawning and rapid development—present new problems in the field of fishery management.

SUMMARY

An investigation of the distribution of anchovy or "nehu" eggs and larvae in Kaneohe Bay, Oahu, Territory of Hawaii, was conducted during 1948 and 1949. It was exploratory in nature, and was designed partly to determine an efficient sampling program and partly to obtain information on the horizontal, vertical, and seasonal distribution of the eggs and larvae.

In each of four surveys (September, December, March, and June) 23 stations were sampled. Of these, nine were in the southern sector, eight in the middle sector, and six in the northern sector of the bay.

Three nets with respective mouth diameters of 100, 22, and 12.3 cm. were used. The large net and one of the two small nets were towed

simultaneously at each station, first in one direction and then in the opposite direction, just below the surface. In addition, two interim surveys were undertaken to investigate the horizontal and vertical distribution of the eggs and larvae at one station in more detail.

Nehu eggs and larvae were identified and nehu larvae were measured. The bluntly ovoid eggs, typical of several species of anchovy, were readily recognized. Some were obviously damaged during tows; others, amounting to about 5 per cent, were apparently dead at the time of capture.

A study of variability of the data revealed heterogeneity between stations, haul order (A and B), and nets, together with a significant interaction between stations and haul order. From the same analysis, it was found that the small nets were relatively more efficient than the large net, but that this could be attributed in part to loss of plankton from the latter because of rips which developed during one survey, and perhaps also to poor technique in handling the catch in the others.

Two interim surveys were undertaken at one station to determine the reason for the difference between A and B hauls and also to study the variation with depth. Both the heterogeneity in haul order and the interaction between stations and haul order could be explained on the basis of non-random distribution of the eggs. Apparently there was a focus of abundance of eggs, and gradients of decreasing abundance extending outward in all directions. Slight variation in the course followed by the vessel in making the hauls would produce large variation in catch because the egg concentration would be transversed at different distances from the focus.

The eggs were slightly more abundant toward the surface than at a depth. A gradient of decreasing abundance with depth was postulated.

Both eggs and larvae were present in all four surveys, showing that spawning takes place throughout all seasons of the year. Whether it is generally more intensive during the summer than during the winter remains to be determined.

Both eggs and larvae were generally most abundant in the southern sector of the bay, less abundant in the middle sector, and least abundant in the northern sector.

Neither eggs nor larvae were randomly distributed within sectors. In the southern sector there was evidently a focus of abundance of eggs in the northerly part. This peculiar distribution is probably related to the current pattern, with the eggs being held in an eddy. There are indications that the larvae are distributed in a similar manner to the eggs when first hatched, but that they gradually disperse as they become larger and older, and tend to become concentrated in the southern part of the bay. In the middle and northern sectors there were several foci of abundance of eggs, their presence and location probably depending on the time and place of spawning and the prevailing current system.

Several modes were evident in the length frequency distribution of the larvae. These were tentatively interpreted as day groups, and indicated an absolute growth rate of about 1.5 mm. per day during the initial growth period. The results suggest a remarkably short period between hatching and recruitment to the fishery, and a rapid overturn in the population, a situation which is probably typical of anchovy populations in tropical waters.

Based on the results of this preliminary work, a sampling program designed to measure total annual egg production in Kaneohe Bay was suggested. Details of gear, stations, and hauls were briefly discussed. It was recommended that, if possible, some other method of collection be used to determine the abundance of larvae.

The investigation was confined to the waters of Kaneohe Bay. Although it is considered unlikely that nehu eggs occur in large quantity in waters outside the bay, the possibility should be investigated in the future.

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Food and Feeding Habits of the Nehu, *Stolephorus purpureus* Fowler[1]

ROBERT W. HIATT[2]

INTRODUCTION

THE NEHU, *Stolephorus purpureus* Fowler,[3] comprises about 95 per cent of all the baitfish used by tuna fishermen in Hawaii. Despite the fact that this species is widely used for live-bait, the baiting grounds are highly restricted in extent throughout the main Hawaiian Islands and differ markedly in their productivity. The most important baiting areas have been mapped in a recent paper which deals with racial segregation of nehu among the main Hawaiian Islands (Tester and Hiatt, in press). It suffices here to state that Kaneohe Bay, located on the northeast side of Oahu, is the leading baiting ground in Hawaii, producing, according to statistics compiled by the Territorial Division of Fish and Game, approximately 60 per cent of the total commercial catch.

Ecologically, nehu appear to be restricted to sheltered coastal waters which are somewhat less saline than oceanic water, although the adults live without noticeable deleterious effect in baitwells of tuna boats at sea and, on occasion, have been observed outside the reefs in waters completely oceanic in composition. Inshore areas suitable for nehu are scarce around the Hawaiian Islands, and in a few of these baiting grounds the population density is often great. The importance of this species to the tuna industry, coupled with the fact that the supply available in these few areas is somewhat precarious, as evidenced by the recent decline in the nehu population in Hilo Bay, has indicated the need for an intensive study of its biology and population dynamics.

Only two brief references to the food and feeding habits of this species exist (Hiatt, 1947*a*: 241; 1947*b*: 271), but, since these do not treat this subject in sufficient detail, the present study on the food and feeding habits of adult nehu was undertaken. Fish from five different baiting areas are analyzed to ascertain if differences and similarities in food habits may be related to variations in their size and vigor. Where adequate data are available, a comparison is made between the food organisms available and the food organisms eaten throughout the year.

METHODS

Collections of fish were made both through the cooperation of commercial fishermen and by the use of the fishery research vessels of the Hawaii Marine Laboratory and the Territorial Division of Fish and Game. With the exception of the fish taken in Ala Wai Canal and in Pearl Harbor, most fish were caught by night-baiting methods, as described by June (1951). The fish taken in the two areas mentioned were seined during early morning day-baiting operations (June, *op.cit.*).

Fish samples were obtained from Ala Wai Canal and from Kaneohe Bay during all seasons of the year. Although collections were sparse in Pearl Harbor, Honolulu Harbor, and Hilo Bay, these data are included because the consistent year-round supply of the important food organisms in a particular area in Hawaiian waters (see Tables 3 and 6) and the consistency of the organisms eaten month to

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[3] The confused generic designation of this species within the family Engraulidae has been discussed by Gosline (1951).

month in a given area (see Tables 4 and 7) result in the diet for any period agreeing rather closely with the average daily diet throughout the year. Thus, an adequate sample for a single month, while appearing scanty for year-round appraisal, has much more value in this area than it would where extensive seasonal variation is the rule. Table 1 indicates the number of fish examined each month for each locality.

The stomach of each fish was removed and opened, and the contents were washed into a Syracuse watch glass. The organisms present were identified to the most exclusive taxonomic category practicable, then counted and recorded.

For each area these calculations were made: the average percentage by number of the complete stomach contents which each type of organism constituted; the average number of organisms in the stomachs; and the percentage of stomachs containing the organism. Emphasis is laid upon percentages by number rather than upon volume. While this method is not altogether satisfactory because the size of the different food elements varies considerably, it provides the best general idea of the relative importance of the various components because of the selective method of feeding. To circumvent misconceptions arising from such treatment of data of this sort Hardy (1924: 19), dealing with food analyses of herring, gave increased values to larger organisms to compensate for larger size. This practice has not been followed in this paper, so it must be borne in mind that ghost shrimps, hyperiid amphipods, crab megalopa, and shrimps are considerably larger than copepods and barnacle larvae. Since data are presented by areas, and since the size range among food organisms taken in each area is not as great as in the food of some other species of fish, the percentages would not be greatly altered if compensation were made for variation in size of organisms. The only important difference in sizes occurs where copepod eggs are present in considerable quantity. The data for Kaneohe Bay and Pearl Harbor should be considered with this difference in mind because adult copepods are many times larger than their eggs.

In tabulating the data, the collections were grouped according to locality, and the general mean for an area was obtained by averaging the totals for the year. The results of the food analyses are summarized for Kaneohe Bay in Table 2, for Ala Wai Canal in Table 5, for Honolulu Harbor in Table 8, for Pearl Harbor in Table 9, and for Hilo Bay in Table 10. The relative importance (percentage by number) of the most important food organisms consumed in each area is diagrammed in Figure 1 so that food habits in the five areas may be compared. To assess objectively the extent to which nehu depend upon the various components of the plankton, an analysis was made of the gross aspects of the month to month fluctuation in plankton organisms in Kaneohe Bay and Ala Wai Canal (Tables 3 and 6). Possible seasonal change in food habits of nehu in these two baiting areas was determined by tabulating the food organisms present in the stomachs month by month (Tables 4 and 7).

TABLE 1

The Number of Nehu Examined Each Month for Each Locality

LOCALITY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
Kaneohe Bay......	4	8	10	–	8	–	5	12	19	6	8	–	80
Ala Wai Canal.....	–	1	3	–	56	–	17	–	–	4	–	–	81
Pearl Harbor......	2	–	–	2	–	–	–	–	–	17	–	–	21
Honolulu Harbor..	–	–	–	–	–	–	20	–	–	–	–	–	20
Hilo Bay..........	–	–	–	–	–	–	–	20	–	–	–	–	20
													222

TABLE 2

FOOD OF NEHU (*Stolephorus purpureus*) IN KANEOHE BAY, OAHU, BASED ON AN ANALYSIS OF 80 STOMACHS

ORGANISM	PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED	AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM	PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS
Copepods			
adults	79	16	35
eggs	30	23	19
Shrimps			
adults	6	1	TRACE
mysis	29	19	15
zoeae	5	11	1
Barnacle larvae			
nauplii	25	20	13
cypris	25	7	5
Crab zoeae	25	12	8
Amphipods (Hyperiidae)	11	7	2
Ghost shrimps (*Leucifer faxonii*)	11	2	1
Isopods	4	2	TRACE
Gastropod veliger larvae	1	1	TRACE
Ostracods	1	2	TRACE
Stomatopod larvae	1	8	TRACE
Fish larvae	1	3	TRACE
Diatoms	3	4	TRACE

Acknowledgments: Personnel of the Hawaiian Tuna Packers Corporation and commercial fishermen belonging to the Tuna Boat Owners Association were very helpful in securing samples of nehu for this study. Fishery biologists employed by the Territorial Division of Fish and Game and by the University of Hawaii have been most cooperative in securing specimens for analysis. To all these individuals the writer extends his appreciation for their interest and assistance.

ANALYSIS OF FOOD AND FEEDING HABITS

Food organisms eaten: Reference to Figure 1 will show certain local differences in the kinds and proportions of food items taken by nehu. Copepods—either adults, nauplii, or eggs—predominate in nehu taken in Kaneohe Bay, Pearl Harbor, and Hilo Bay, with the latter two areas much alike in the items and proportions thereof taken. In the remaining two areas, Ala Wai Canal and Honolulu Harbor, copepods are of little or no importance to nehu as food, the chief items eaten being ghost shrimps (*Leucifer faxonii*) and crab megalopa. In most cases the largest fish in a sample contained the greatest volume of food, and the stomachs of the characteristically large nehu from Ala Wai Canal and Honolulu Harbor were usually greatly distended, as compared with the rarely distended stomachs of smaller fish distinctive of other areas. The monthly distribution of food organisms taken in Kaneohe Bay (Table 4) and in Ala Wai Canal (Table 7) shows very little change during any period of the year in regard to the more important dietary items.

A comparison of the food habits of the nehu with other anchovies is not very satisfactory because so few comparable studies have been made. Similar components of the zooplankton are taken by the Mediterranean anchovy, *Engraulis encrasicholus* (Miranda y Rivera, 1930), and by a Japanese engraulid, *Coilia mystus* (Suyehiro, 1942), which has an alimentary canal almost identical with that of the nehu. However, certain fundamental differences in the diet of other anchovies are ap-

TABLE 3

MONTHLY DISTRIBUTION OF THE DOMINANT PLANKTON COMPONENTS IN KANEOHE BAY, OAHU, BASED ON ROUTINE BI-WEEKLY HAULS IN AREAS OCCUPIED BY NEHU. THE SYMBOL xxx DENOTES GREAT ABUNDANCE, xx DENOTES COMMON OCCURRENCE, AND x DENOTES UNCOMMON OR RARE OCCURRENCE

ORGANISM	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Chaetognatha (*Sagitta*)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Copepods (nauplii and adults)	xxx	xx	xxx	xx	xx	xxx	xx	xx	xxx	xx	xxx	xxx
Ctenophora	xxx	xxx	xxx	xxx	xx	xxx	xxx	xxx	xx	x	xxx	xxx
Shrimp larvae (mysis)	xx	xx	xx	x	x	xx	x	x	xx	x	xx	x
Shrimp larvae (zoeae)	xx	x	xxx	x	x	xxx	x	xx	xx	x	xx	xx
Crab larvae (zoeae)	xx	xxx	xxx	xxx	xx	xxx	x	xx	xxx	xxx	x	xxx
Ghost shrimps (*Leucifer faxonii*)	–	–	xx	x	xx	xx	xx	x	x	–	x	x
Barnacle larvae (nauplii)	x	xx	x	–	–	–	–	x	x	xx	xxx	xxx
Barnacle larvae (cypris)	–	x	–	–	–	–	–	–	–	–	–	–
Amphipoda (Hyperiidae)	–	x	x	x	x	x	x	xx	xx	–	–	–
Tunicata (Larvacea)	x	x	x	x	x	x	x	xx	x	xx	x	x
Gastropod and pelecypod larvae	x	x	x	x	x	x	x	–	–	–	x	–
Ostracoda	–	–	x	x	–	x	x	x	–	–	x	x
Stomatopoda larvae	–	–	x	–	–	xx	–	x	x	–	x	x
Isopods	x	–	–	–	–	–	–	–	x	–	–	–
Annelida larvae	–	x	–	x	x	–	–	–	–	–	–	–
Medusae	–	–	x	x	–	–	–	–	–	–	–	–

parent. Although too few fish were examined for reliable results, Allen (1921: 543) reported the stomachs of the West Coast anchovy, *Engraulis mordax*, to contain only diatoms and dinoflagellates, and Suyehiro (1942: 54) showed the Japanese anchovy, *Engraulis japonicus*, to be exclusively a feeder on phytoplankton. Nishikawa (1901), studying this same anchovy, found that the young fed chiefly on copepods and did not specialize on phytoplankton until adulthood was attained. Correspondingly, the intestine of *E. japonicus* is much longer than that of the nehu, and it is suggestive of herbivorous rather than carnivorous habits. The lack of phytoplankton in the diet of Hawaiian anchovies might be attributed to the fact that diatoms and dinoflagellates are very sparse in the Hawaiian area.

TABLE 4

MONTHLY CHARACTERISTICS OF THE FOOD HABITS OF NEHU IN KANEOHE BAY. THE SYMBOL x DENOTES OCCURRENCE IN STOMACH CONTENTS

ORGANISM	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Copepods (nauplii and adults)	x	x	x	–	x	–	–	x	x	x	x	–
Barnacle larvae (nauplii)	x	x	x	–	x	–	–	x	x	–	–	–
Barnacle larvae (cypris)	x	x	x	–	x	–	–	–	–	–	–	–
Crab zoeae	–	–	x	–	–	–	x	x	x	x	–	–
Shrimps	–	–	–	–	x	–	x	–	–	–	–	–
Shrimp larvae (zoeae)	–	–	–	–	–	–	–	–	–	x	–	–
Shrimp larvae (mysis)	x	–	–	–	x	–	–	x	x	x	–	–
Ghost shrimp (*Leucifer faxonii*)	–	–	–	–	–	–	–	x	x	–	–	–
Amphipoda (Hyperiidae)	–	–	–	–	–	–	–	x	x	–	–	–
Isopods	–	–	–	–	–	–	–	x	x	–	–	–
Stomatopoda larvae	–	–	–	–	–	–	–	x	–	–	–	–
Fish larvae	–	–	–	–	–	–	–	–	x	–	–	–
Ostracoda	–	–	–	–	–	–	–	–	x	–	–	–
Veliger larvae	–	–	–	–	–	–	–	–	–	x	–	–

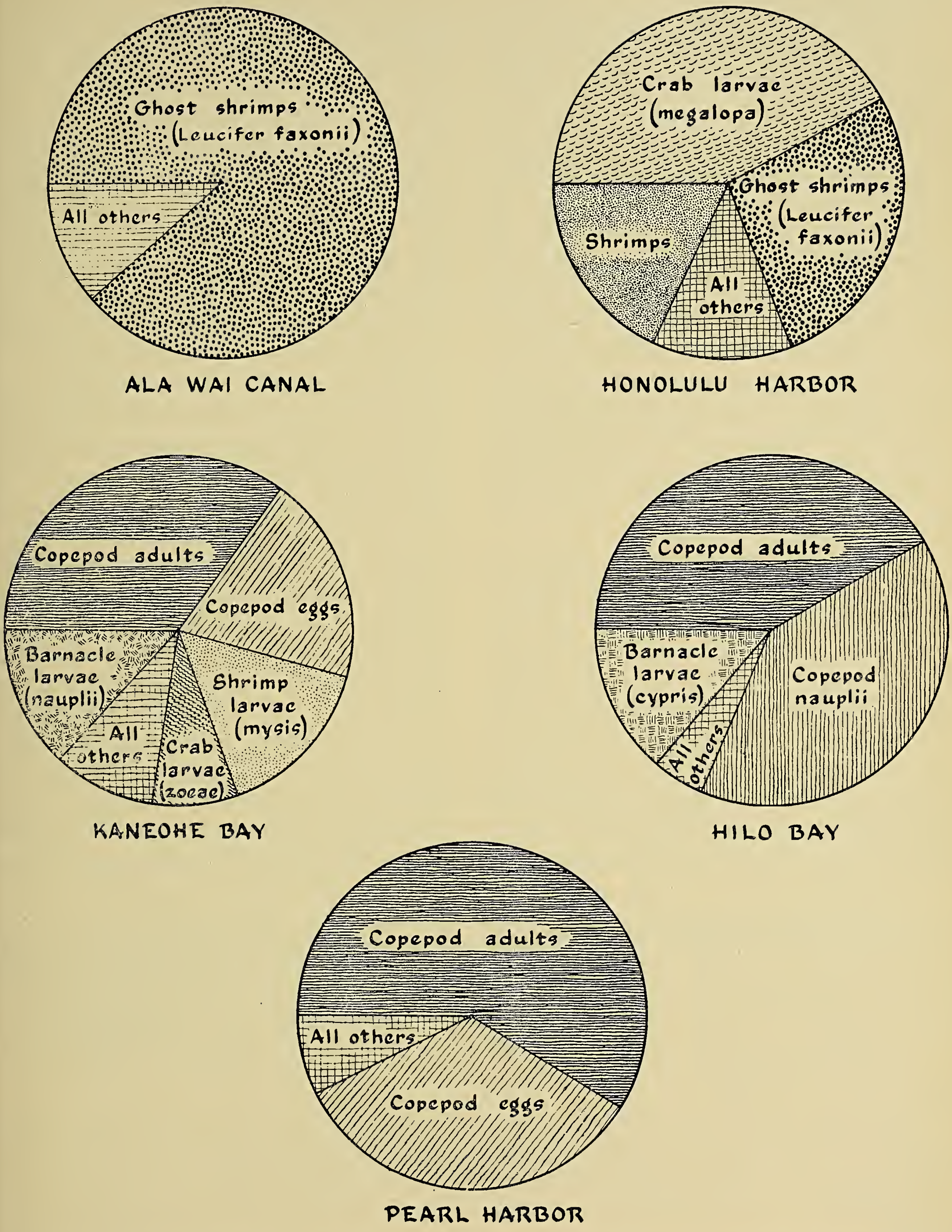

FIG. 1. Summary of the food habits of nehu from the five baiting areas investigated in this study.

The food and feeding habits of nehu and other engraulids are quite similar to those of the closely related clupeids. Herring in the North Pacific (Kuragami, 1930; Wailes, 1935), in the North Atlantic (Moore, 1898; Weber and Wilson, 1920; Bigelow and Welsh, 1925), and in European waters (Widegren, 1876; Lebour, 1924; Hardy, 1924; Jespersen, 1928; Savage, 1931, 1937; Lucas, 1936) all consume about the same components of the zooplankton as do nehu. Sardines, both in Japanese and California waters (Suyehiro, 1942), consume a good deal of phytoplankton as well as zooplankton, with the composition of the stomach contents roughly proportional to the composition of the plankton. Thus, the food habits of nehu resemble those of herring more closely than those of sardines, yet there are other anchovies which feed more like sardines than like herring.

Selective feeding: The question of selective feeding may best be answered by considering the feeding habits in each area for which data have been collected on available food organisms. A comparison of Tables 2 and 3 for Kaneohe Bay indicates that (1) nehu do not accept planktonic forms indiscriminately, because few plankters other than crustaceans are eaten, although the dominant components of the plankton are chaetognaths and ctenophores; and (2) nehu do take the dominant crustacean types, about in proportion to their occurrence; i.e., copepods, mysis larvae of shrimps, zoeal larvae of crabs, and nauplii of barnacles, which are the most abundant forms found in the stomach contents, also predominate in the available plankton.

A similar analysis was made in Ala Wai Canal (Tables 5 and 6) with quite different results. Here ghost shrimps predominate by far in the stomach contents, and nine out of every ten fish contained them. By comparing the data in the tables indicated above, it is clear that in this locality (1) nehu do discriminate among the total composition of the plankton, e.g., they did not contain any medusae, isopods, chaetognaths, or polychaetes, and (2) nehu do not accept the crustaceans present in the plankton in the order of their abundance. From the standpoint of organisms available, crab zoeae and barnacle nauplii exceeded by far the number of ghost shrimps present, yet the percentage composition of the food items consumed, based on the total number of organisms found in the stomachs, shows that ghost shrimps were unquestionably preferred. The smaller, but more abundant crustaceans such as crab zoeae, barnacle nauplii, copepods, and the zoeal and mysis larvae of shrimps were almost neglected, and in no case did as much as 10 per cent of the fish examined take them,

TABLE 5

FOOD OF NEHU (*Stolephorus purpureus*) IN ALA WAI CANAL, HONOLULU, BASED ON AN ANALYSIS OF 81 STOMACHS

ORGANISM	PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED	AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM	PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS
Ghost shrimps (*Leucifer faxonii*)	91	27	90
Shrimps			
mysis stage	5	15	3
zoeae	5	9	2
Barnacles			
cypris stage	10	9	3
nauplii	1	3	TRACE
Copepods			
adults	9	4	1
eggs	1	3	TRACE
Crab zoeae	6	1	TRACE
Filamentous algae	1	1	TRACE

TABLE 6

MONTHLY DISTRIBUTION OF THE DOMINANT PLANKTON COMPONENTS IN ALA WAI CANAL, HONOLULU, BASED ON ROUTINE BI-WEEKLY HAULS IN AREAS OCCUPIED BY NEHU. THE SYMBOL xxx DENOTES GREAT ABUNDANCE, xx DENOTES COMMON OCCURRENCE, AND x DENOTES UNCOMMON OR RARE OCCURRENCE

ORGANISM	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Ghost shrimps (*Leucifer faxonii*)	xxx	xxx	xxx	xxx	xx	xx	xx	x	xx	xx	xx	xx
Crab zoeae	xx	xx	xx	xxx	xx	xxx	xxx	xx	xxx	xxx	xxx	xxx
Barnacle larvae (nauplii)	xx	x	xx	xxx	xx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Copepods	xxx	xxx	xx	xx	x	xxx	xx	x	xxx	x	x	xxx
Medusae	xxx	x	x	x	xxx	xxx	xx	x	x	xxx	xx	xxx
Shrimp larvae (mysis)	x	x	x	x	x	xx	x	x	xx	x	xx	xxx
Shrimp larvae (zoeae)	xx	x	xx	x	x	xx	x	x	x	xx	x	xxx
Isopoda	x	–	xxx	xxx	xx	x	–	–	x	–	x	x
Chaetognatha (*Sagitta*)	–	xx	xx	–	–	x	x	–	x	–	–	x
Polychaeta	–	–	x	x	x	x	x	–	–	–	–	–

notwithstanding their continued presence in abundance throughout the year. Of importance in understanding the differential selection of food in Ala Wai Canal is the fact that ghost shrimps are exceedingly abundant there, the population density per unit volume being many times greater than that in Kaneohe Bay. Somewhat anomalous is the apparent disregard by nehu in Kaneohe Bay of ghost shrimps and hyperiid amphipods which are available during most of the year, although in much smaller quantities than in Ala Wai Canal.

In regard to the selection of food organisms, the food habits of nehu in Honolulu Harbor (Table 8) are quite similar to those in Ala Wai Canal. Nehu here depend chiefly on the larger crustacean elements in the plankton, with crab megalopa, ghost shrimps, and small palaemonid shrimps comprising the bulk of the food. Small plankters were taken incident to larger items only by a few fish, and these plankters constituted less than 10 per cent by number of all the organisms taken. The rather small nehu from Pearl Harbor consumed mostly copepods and a smaller quantity of crab zoeae (Table 9). An analysis of the plankton (unpublished MS.) indicates that copepods comprise the most important component, with crab and shrimp zoeae ranking second and third, respectively. It is apparent that nehu in this area exercise little or no selection among the plankters except to ignore organisms other than crustaceans. No quantitative data are available for plankton in Hilo Bay, but the results of several tows made incident to a survey of pollution in the bay indicate a very low population density, and the organisms present are comparatively very small in size. No ghost shrimps, amphipods, larval shrimps, or crab megalopa were found. The minute food items found in the stomachs of fish from this area were present in about the same proportion as they occurred in the plankton. The above analyses indicate that the nehu is definitely a feeder on the

TABLE 7

MONTHLY CHARACTERISTICS OF THE FOOD HABITS OF NEHU IN ALA WAI CANAL. THE SYMBOL x DENOTES OCCURRENCES IN STOMACH CONTENTS

ORGANISM	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
Ghost shrimps (*Leucifer faxonii*)	–	–	x	–	x	–	x	–	–	–	–	–
Copepods	–	x	–	–	x	–	–	–	–	x	–	–
Barnacle larvae (cypris)	–	x	x	–	–	–	–	–	–	x	–	–
Crab zoeae	–	–	x	–	x	–	–	–	–	–	–	–
Shrimp zoeae	–	–	–	–	x	–	–	–	–	x	–	–

TABLE 8

FOOD OF NEHU (*Stolephorus purpureus*) IN HONOLULU HARBOR, OAHU, BASED ON AN ANALYSIS OF 21 STOMACHS

ORGANISM	PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED	AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM	PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS
Crab larvae			
megalopa	100	20	42
zoeae	25	10	5
Ghost shrimps (*Leucifer faxonii*)	70	18	27
Shrimps			
adults	40	21	18
mysis	15	10	3
Copepods	40	6	5
Barnacle larvae (cypris)	10	2	TRACE

crustacean components of the zooplankton, and that selection of crustacean types is apparent in some areas and lacking in others.

From the standpoint of selection of food items, nehu resemble herring more nearly than they do sardines. While opinion is divided on the question of selection of plankters by sardines, most investigators agree that there is little or no selection exercised (Kishinouye, 1907; Lewis, 1929; Suyehiro, 1942), but Parr (1930) believes that phytoplankton is ingested only incidentally while sardines pursue zooplankton. Overwhelming evidence for selection in the feeding of herring has been advanced by Moore (1898), Hardy (1924), Bigelow and Welsh (1925), Bigelow (1926), Jespersen (1928), Savage (1931, 1937), Lucas (1936), Wailes (1935), and Johnson (1940). It is generally agreed that herring feed by active pursuit on sight and that adult fish ignore the smallest forms of copepods even though they may be the most abundant in the plankton. The plankters selected showed nice agreement between the occurrence in the herring food and in plankton samples. These findings are comparable to those discovered for nehu. Lebour (1920: 262) aptly sums up this subject for herring and other small plankton feeding fishes, except possibly the sardine, by stating: ". . . usually each species of fish selects its own favourite food, to which it keeps, indiscriminate feeding seldom or never taking place. . . ."

Ingestion: To learn how nehu ingest their food, a small school was confined in a display tank into which living ghost shrimps were then placed. The fish swam quickly to the shrimps and ate them without slackening their swimming speed. When a nehu sighted a ghost shrimp to one side it would make a quick sideways movement in turning to reach the shrimp. In doing this the whole body partly turns over producing a flash from the silvery side when viewed from above. This sideways movement and silvery flash are one of the characteristic features of a school of nehu, and serve to distinguish nehu from another important baitfish, the iao (*Pranesus insularum*), during both day and night baiting operations. Captive herring have been observed to behave similarly (Johnson, 1940: 392).

Relation of size of fish to size of food: Length-frequency plots of nehu in the commercial catch for the various baiting areas clearly show characteristic differences in the average size of fish (unpublished data). Certain of the areas involved in this study (Ala Wai Canal and Honolulu Harbor) can always be depended upon to provide larger fish than the other areas mentioned. The nehu in Kaneohe Bay and in Pearl Harbor are characteristically small in size, with those in Hilo Bay still smaller. Obviously, factors other than food supply may operate to regulate the average size composition of a fish population, such as (1) differences in fishing intensity from one area to the next, or (2) hereditary differences in growth rate. Unfortunately, the effect of fishing intensity on the population characteristics of nehu is unknown. Furthermore, while racial segregation, as evidenced by an analysis of meristic features, has been shown between certain areas, it has not been shown for others (Tester and Hiatt, in press), so no conclusions may be drawn concerning hereditary differences in growth rate from one area to the next. We do know that (1) the average size of fish in the commercial catch differs between areas but is rather consistent within an area, (2) the composition of the plankton differs between areas but is rather consistent within an area, and (3) large nehu exercise some selection and take mostly the larger forms among the available crustacean plankters, while small nehu seem to take the smaller crustacean components in about the same proportion as they occur in the plankton. From these data certain implications may be made concerning the relation of the size of fish to the size of food.

It was noted previously that a predilection for certain abundant, large crustacean plankters and a virtual disregard for even more abundant but smaller crustacean plankters was apparent in nehu living in Ala Wai Canal and Honolulu Harbor. Both these areas produce nehu of comparatively large size. The medium-sized nehu of Kaneohe Bay and Pearl Harbor and the very small nehu of Hilo Bay do not exercise appreciable selection among the crustacean elements in the plankton. In Kaneohe Bay and in Pearl Harbor large crustacean plankters are sparse in contrast with similar forms in Ala Wai Canal and Honolulu Harbor, while in Hilo Bay large crustaceans are absent and smaller ones are sparse. Thus there appears to be a positive relationship between the size of fish and the size of crustacean plankters available, and a relationship between the size of fish and the size of crustacean plankters consumed. With regard to the former, it appears possible that nehu may not exceed a certain size unless a sufficient quantity of food of the proper type and size is available. Underlying reasons for such a hypothesis involve nutritional demands per unit of time on the part of the fish and the proportional protein content of small versus larger crustaceans, subjects on which no data are available. With food organisms ranging from minute to large sizes, available in adequate amounts, it is possible that the growth rate of nehu is sufficiently rapid to provide characteristically larger fish to the commercial catch in certain areas. Where the food supply lacks organisms beyond a certain size, growth may slacken appreciably as the fish becomes larger and nehu of characteristically smaller average size might result in other areas.

TABLE 9

FOOD OF NEHU (*Stolephorus purpureus*) IN ULUMOKU POND, PEARL HARBOR, OAHU, BASED ON AN ANALYSIS OF 21 STOMACHS

ORGANISM	PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED	AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM	PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS
Copepods (*Acrocalanus inermis*)			
adults	90	83	60
eggs	90	47	34
Crab zoeae	86	6	4
Shrimps (*Leander debilis*)			
zoeae	10	1	TRACE
megalopa	10	21	2
Barnacle larvae (cypris)	48	1	TRACE
Ghost shrimps (*Leucifer faxonii*)	5	1	TRACE

TABLE 10

FOOD OF NEHU (*Stolephorus purpureus*) IN HILO BAY, HAWAII, BASED ON AN ANALYSIS OF 20 STOMACHS

ORGANISM	PERCENTAGE FREQUENCY OF OCCURRENCE AMONG FISH EXAMINED	AVERAGE NUMBER TAKEN PER FISH CONTAINING THE ITEM	PERCENTAGE COMPOSITION OF FOOD ITEMS BASED ON TOTAL NUMBER OF ORGANISMS FOUND IN THE STOMACHS
Copepods			
adults	80	9	41
nauplii	55	13	40
Barnacle larvae			
cypris	80	3	14
nauplii	10	7	4
Nehu scales	30	–	–
Crab zoeae	5	4	1

With regard to the relationship between the size of fish and the size of organisms consumed, it is probably a function of the abundance of organisms of various sizes combined with the physical ability of the fish to catch and ingest them. Ghost shrimps are not present in the stomachs of small nehu, even in areas where these crustaceans are abundant. Large fish in areas where large crustaceans are abundant in the plankton naturally select them over small crustaceans because they can ingest organisms of larger size and their nutritional requirements would probably be fulfilled in less time and with less energy expended. Fish in areas lacking larger crustacean plankters have no choice in the matter.

Relation of food to vigor: Fishermen are cognizant of the differences in the characteristic vigor of nehu caught in the various baiting areas. The small fish from Hilo Bay and Kaneohe Bay seem less able to withstand the handling and confinement required in catching, transferring, and transporting them to the tuna fishing areas than are the larger and more vigorous fish taken in Ala Wai Canal and Honolulu Harbor. While we have no data which would compare vigor in small and large fish in the same baiting area, it is possible that vigor is directly related to the size of the fish. Small herring, for example, are more fragile and less hardy than large herring because they lose their scales more readily. Some evidence that hardiness in nehu may resemble that for herring was found by examining the stomach contents of nehu caught in Hilo Bay. Approximately one-third of the fish stomachs contained nehu scales. The shiny scales were sighted and ingested as they were shed into the water. The taking of scales would be only of academic interest if it were not for the fact that Hilo Bay nehu are very small, exceedingly fragile and weak, and difficult to maintain alive in bait wells. If these small nehu lose their scales more readily than do larger nehu, as is true for herring, the excessive fragility may be associated with the small size. Although we have insufficient evidence at present, further study on the relation of vigor to size and of size to food available may indicate the principles underlying the apparent differences in size and vigor of nehu in the various baiting grounds.

SUMMARY

Investigations into the food and feeding habits of the nehu, the leading livebait fish for tuna in Hawaiian waters, were conducted for five important baiting areas in Hawaii. A total of 222 stomachs of fish from the commercial catch was analyzed for food contents. A gross quantitative analysis of the principal plankton species present in two areas was made for a comparison between the food items consumed and the organisms available.

Copepods, barnacle nauplii, and mysis larvae of shrimps were most important in the diet of nehu taken in Kaneohe Bay; ghost shrimps (*Leucifer faxonii*) predominated in

fish from Ala Wai Canal; in Honolulu Harbor nehu food was mostly crab megalopa, ghost shrimps, and small palaemonid shrimps; and copepods predominated in stomach contents of nehu from Pearl Harbor and Hilo Bay. Very little seasonal change occurs in the kinds and proportions of the more important dietary items.

Nehu are selective feeders in that they take only the crustacean elements in the plankton. Selection among certain crustacean types is apparent in some areas and is lacking in others.

The characteristically larger nehu in Ala Wai Canal and in Honolulu Harbor show a predilection for large crustacean plankters and a virtual disregard for the more abundant smaller crustacean types, whereas the usually smaller nehu of other areas ignore the few large types available and consume the smaller forms in about the same proportions as they occur in the plankton. The baiting areas which have an abundant supply of the larger crustacean elements in the plankton contain the largest fish, while those areas which support only a sparse population of these larger plankters, or none at all, contain the smallest fish.

Further study on the relation of vigor to size and of size to food available may indicate the principles underlying the apparent differences in size and vigor of nehu in the various baiting grounds.

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The Origin, Development, and Nature of the Spermatophoric Mass of the Spiny Lobster, *Panulirus penicillatus* (Oliver)[1]

Donald C. Matthews[2]

INTRODUCTION

Although many thorough investigations of crustacean spermatozoa have been made, few have included more than desultory accounts of the spermatophores. The material presented in this paper not only extends our knowledge of the biology of the spiny lobster *Panulirus penicillatus* (Oliver) through an account of the origin, development, and nature of its spermatophoric mass, but also suggests the method by which its spermatozoa are liberated.

Early cursory observations on crustacean spermatophores by Cavolini, Kölliker, and Schwammerdam, cited in Herrick (1895: 160), apparently failed to stimulate further interest in this direction, but possibly served to incite such workers as Grobben (1878), Hermann (1890), Sabatier (1893), Brandes (1897), Labbé (1903), and Koltzoff (1906) to investigate more thoroughly the nature of decapod spermatozoa. These early works illustrate the interest in the spectacular decapod spermatozoa to the neglect of the spermatophores.

With the exception of the early work of Herrick (*op. cit.*) on the reproductive system of the American lobster (*Homarus americanus*), investigations of the spermatophores of macrurans were singularly lacking until Dahlgren and Kepner (1908) attributed to the lobster and the crayfish a fluid which, secreted by the walls of their sperm ducts, not only served as a vehicle to carry the mass of sperm but also formed a semifluid covering around them. Dahlgren and Kepner further reported that the spermatophore attached itself to a receiving plate on the female, became hard, and preserved the life of the spermatozoa for months or even years. No reference is made however to the species of lobster and crayfish which produced these spermatophores.

No particular differentiation between the non-pedunculate spermatophores of the Macrura and the more bizarre pedunculate spermatophores of the Anomura and Brachyura was noted in the literature until Calman's treatise in 1909. Since that time considerable research has ensued on the pedunculate type, and, culminating in the studies of Mouchet (1930–31), the origin and development of these have become rather well known.

Comparatively little research has been accomplished on the non-pedunculate spermatophore of the Macrura. Allen (1916) first described for a spiny lobster, *Panulirus interruptus*, a spermatophore composed of a putty-like mass of sperm material. This mass, placed on the ventral surface of the female's thorax, contained contorted tubular cavities filled with spermatozoa. He further explained that this mass was at first white and soft but later turned black and became hard, resembling whalebone. Allen's account, as well as Fasten's (1917), on the consistency and color change in the spermatophoric mass of *Panulirus interruptus* is in accord with the findings of this report, but their observations on the contorted tubular cavities were not extensive and little consideration was given to the origin or the development of the mass. Insofar as can be ascertained, no published work on the origin, development, and nature of the spermatophoric mass of *P. penicillatus* has been reported.

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METHODS AND TECHNIQUES

Specimens of *P. penicillatus* taken in the vicinity of Kaneohe Bay, Oahu, between July, 1947, and January, 1948, were used in this study. Males whose carapace length exceeded 10 centimeters were usually found to possess well-developed gonads. These were removed from freshly killed specimens, rolled lightly on blotting paper, weighed, and placed immediately in fixative. A label indicating the catch and specimen number was inserted in each vial so that histological data could be correlated with size, date, and other pertinent information.

For the purpose of routine histological examination the reproductive system (Figs. 1, 2) was divided into: anterior testis (Fig. 2*i*); mid-testis (*e*); posterior testis (*c*); proximal vas deferens (*d*); and the massive distal vas deferens (*h*). Small portions of these regions were placed in Bouin's fixative, which gave excellent preparations for all tissue except the vas deferens which became extremely brittle. Tissues were cleared with toluene, embedded in Tissuemat (54–56° C.) and, for routine investigation, sectioned at 10 microns. Some testis preparations were placed in Bouin's fixative and some in Fleming's, and were cut at 6 and 4 microns. Routine sections were stained with standard alum-haematoxylin and counterstained with eosin (0.5 per cent solution in 90 per cent alcohol to which 04. cc. of 0.1 N HCl was added). Heidenhain's iron-haematoxylin without a counterstain was used with good results in some sections of the testis. Mallory's triple connective-tissue stain was employed to aid in tissue differentiation. Because of the extreme hardness of the enlarged portions of the vas deferens, it was often necessary to coat the surface of the paraffin block with thin celloidin between successive cuts. For examination of the rayed spermatozoa, fresh sections were taken from the enlarged vas deferens, the matrix was separated from the spermatophore, and the spermatophore was opened in sea water.

Figures 1 and 9 were drawn by Florence Lambeth from dissections made by the author. Figures 2, 4, 5, 6, 7, and 8 were drawn by Inger Achton from slides and dissections made by the author. Figure 3 was drawn by Evan L. Gillespie.

The writer acknowledges with thanks the help of Dr. Robert W. Hiatt, who suggested the problem and offered his assistance in many ways throughout the course of the study.

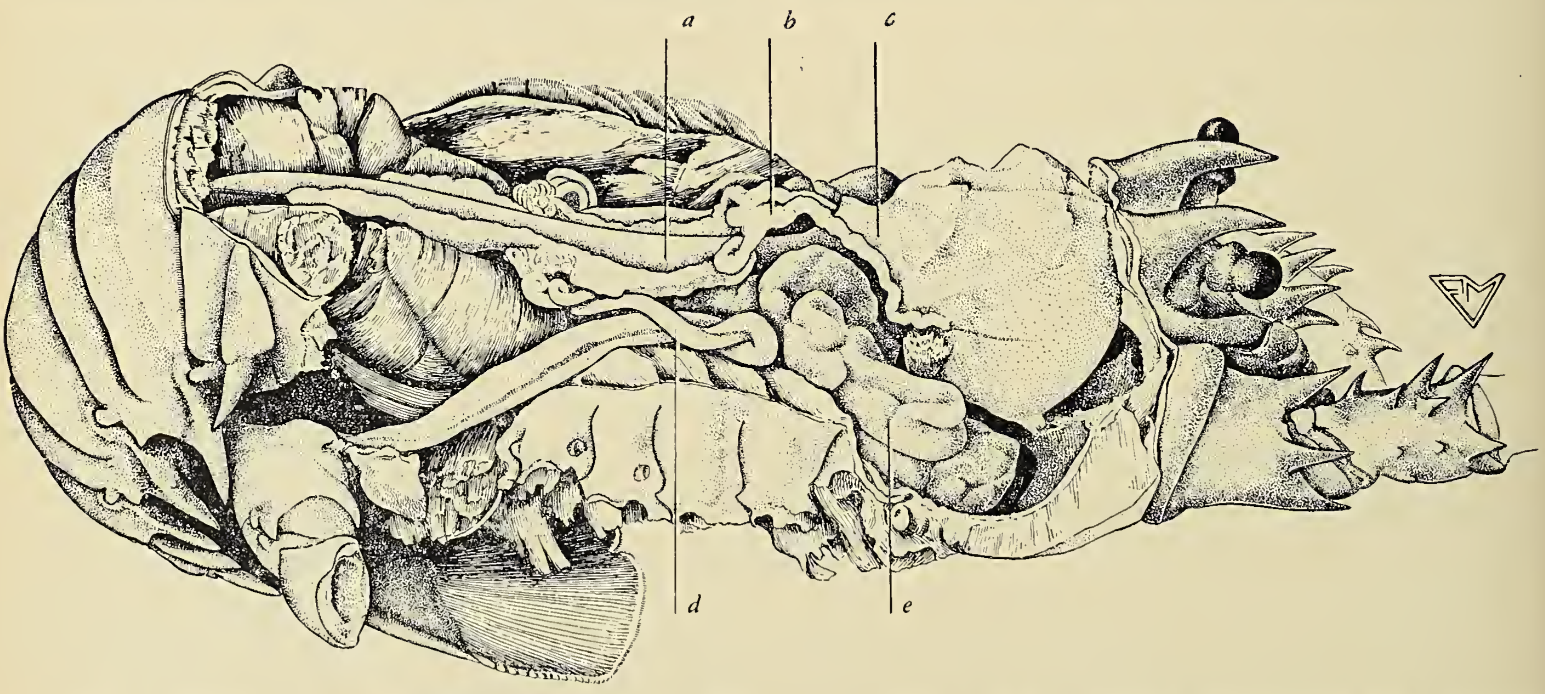

FIG. 1. Dissection of a mature male *Panulirus penicillatus* (Oliver) drawn to show the structure and position of the reproductive system in relation to other structures. *a*, Intestine; *b*, testis just anterior to transverse bridge; *c*, pyloric region of stomach; *d*, enlarged portion of vas deferens; *e*, hepatopancreas. (0.5×)

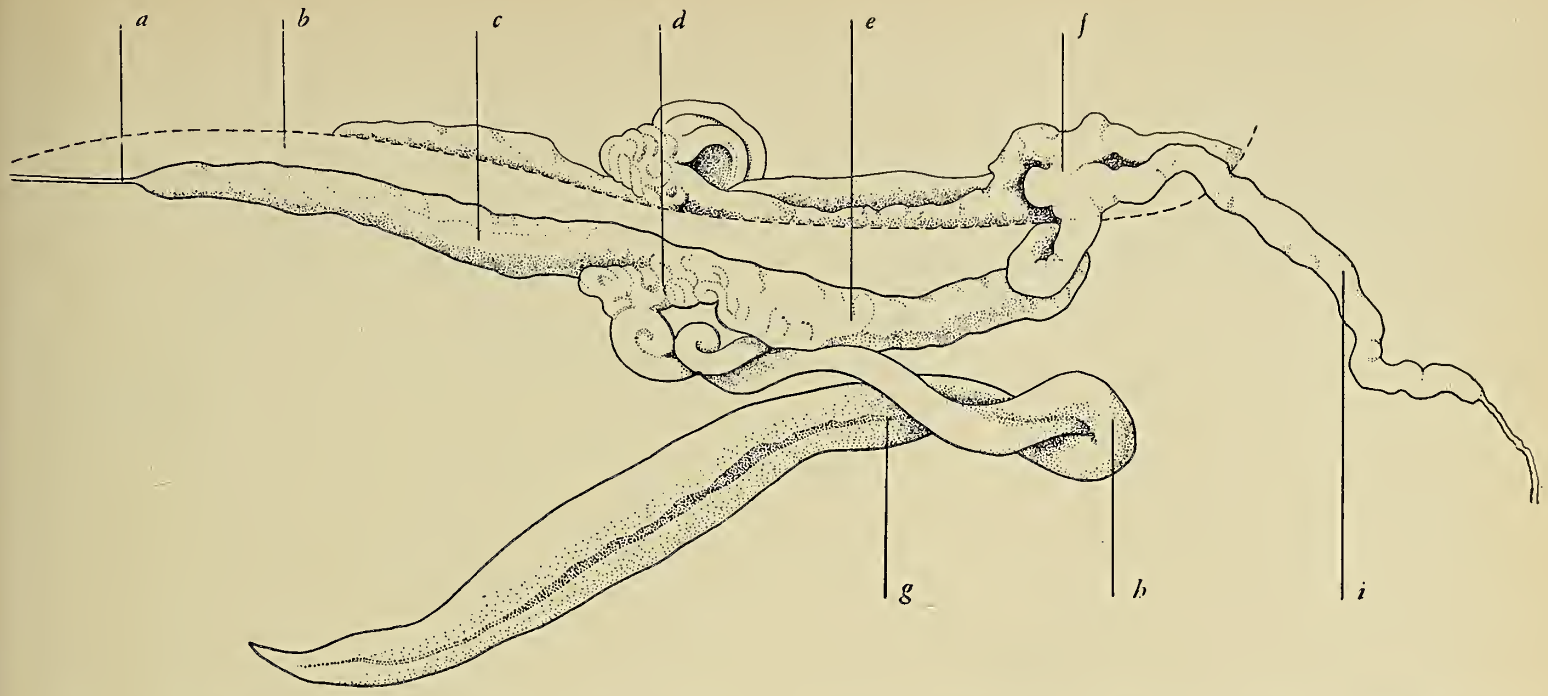

FIG. 2. Male reproductive system enlarged to show: *a*, posterior mesentery of testis; *b*, portion of the digestive tract; *c*, posterior region of testis; *d*, proximal portion of vas deferens; *e*, region of mid-testis; *f*, region of transverse bridges; *g*, hyaline line; *h*, enlarged, swollen portion of vas deferens; *i*, anterior region of testis. (1×)

RESULTS

The testes (Fig. 1*b*) are seen to be long, whitish, sacculate tubes joined one to the other by a transverse bridge (Fig. 2*f*) just posterior to the junction of the pyloric region of the stomach (Fig. 1*c*) with the intestine (*a*). Seen dorsally, the testes resemble an elongated **H** in which the posterior portion (Fig. 2*c*) usually exceeds the anterior portion (*i*) both in length and diameter. With the exception of the anterior distal portion of the testis which, as it encircles the stomach, extends ventrally, the major portion of the anterior testis lies dorsal to the hepatopancreas (Fig. 1*e*) and the digestive tract (Fig. 1*a*, 2*b*). The posterior portion of the testis traverses caudad on either side of the intestine, often slightly ventrad to the digestive tract. It is not uncommon to observe differences in the size of the testicular horns, the right posterior portion often being longer than the left, or vice versa. The testes are held in place by mesenteries (Fig. 2*a*) which extend posteriorly a short distance into the first abdominal segment, and anteriorly appear to be attached ventrad to the stomach.

At the outset of this study it became apparent that an understanding of the origin, development, and nature of the spermatophoric mass made necessary a thorough study of the histology of the testis. Only when the entire testis is studied in serial section can one properly interpret any single section or attempt the more difficult task of reconstruction. Throughout each general region of the testis, follicles observed in any one histological section exhibited various degrees of maturity, although the cells in any one follicle were usually at the same stage of development.

Figure 3 is a diagrammatic reconstruction of the testis. It suggests, somewhat, a paniculate inflorescence, but seems to be a racemose or compound gland of freely branching ducts which terminate in acini, so that the whole resembles a compact cluster of grapes. The reconstruction further shows that the racemose, anterior portion of the testis (*a*) joins ultimately the racemose, posterior portion of the testis (*b*) to form an exceedingly long and highly coiled tube (*c*). This contorted tube traverses the testis for some distance both anteriorly and posteriorly from its place of origin in the mid-testis (*d*) and ultimately emerges as the vas deferens (Figs. 1*d*, 2*d*, 3*e*).

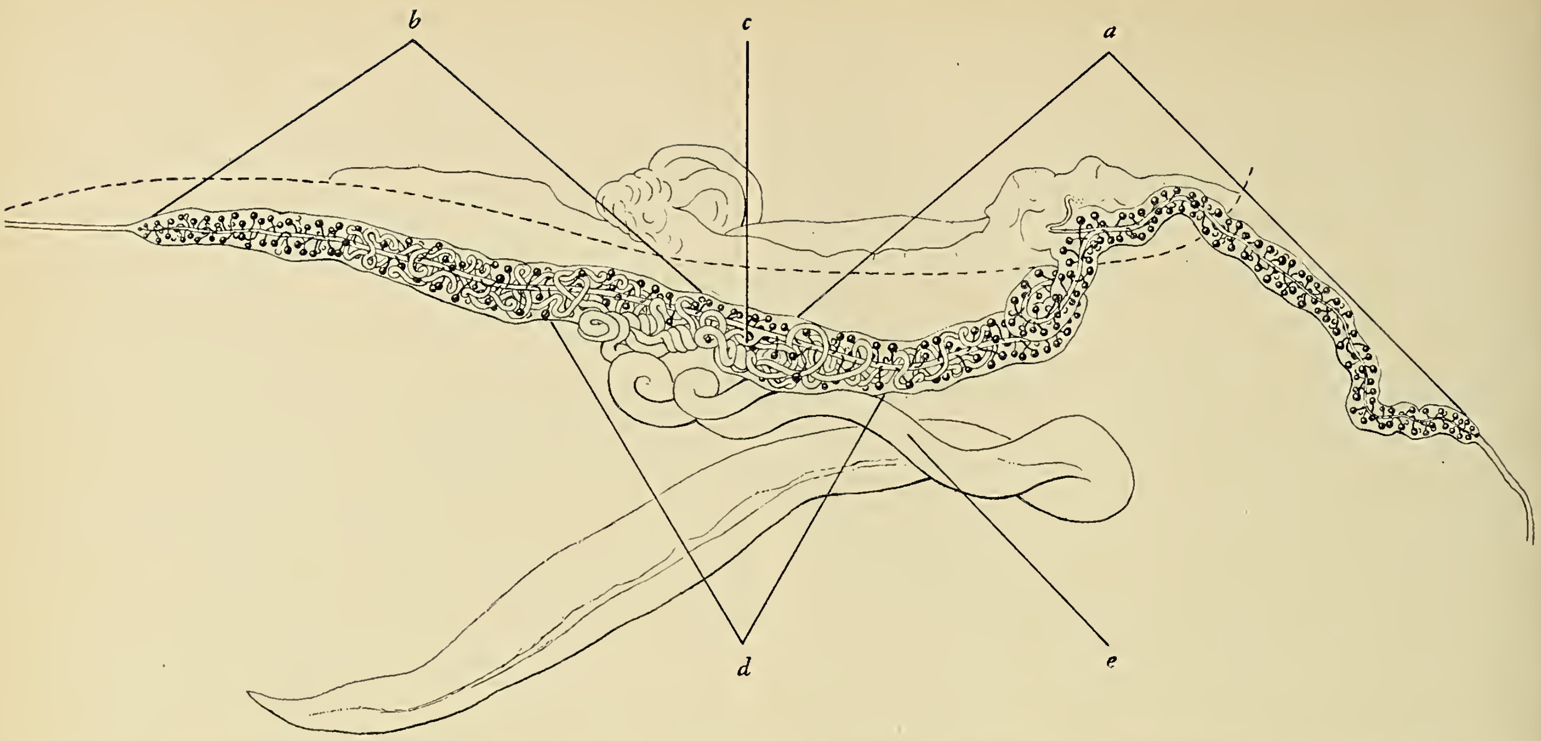

FIG. 3. Diagrammatic reconstruction of the right testis to show: *a*, paniculate anterior portion; *b*, paniculate posterior portion; *c*, tube which ultimately drains regions *a* and *b*; *d*, mid-testis; *e*, vas deferens. (1×)

Figure 4 is a cross section through an immature follicle taken through the anterior part of the testis (Fig. 2*i*). It should be borne in mind, however, that sections taken through the mid-portion of the testis (Fig. 2*e*) or the posterior portion of the testis (*c*) would reveal follicles of similar maturity, and these would also be associated with other follicles of varying degrees of maturity. The entire follicle is filled with large, primary spermatocytes (Fig. 4*b*). These cells measure 15 to 20 microns in diameter and contain nuclei that may attain a diameter of 10 to 14 microns. At this particular stage it is impossible to distinguish the primary spermatocytes from the seminiferous epithelium (Fig. 4*c*).

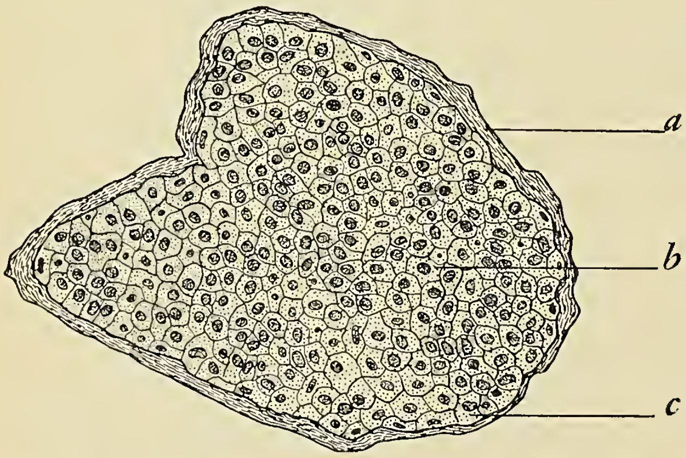

FIG. 4. Camera lucida drawing of portion of testis (Fig. 2*i*). *a*, Connective tissue; *b*, primary spermatocyte; *c*, seminiferous epithelium. (125×)

A transverse section (Fig. 5) as far posterior as the mid-testis (Fig. 2*e*) reveals follicles, some of which are more mature than that illustrated by Figure 4. Follicles at this stage of maturity likewise can be observed in transverse sections throughout the length of the testis, and these would also be associated with other follicles of varying degrees of maturity. A lumen (Fig. 5*g*) and radiating cells (*c*) present a wheel-like appearance in this stage of development. Whereas in Figure 4 the follicle is filled with a homo-

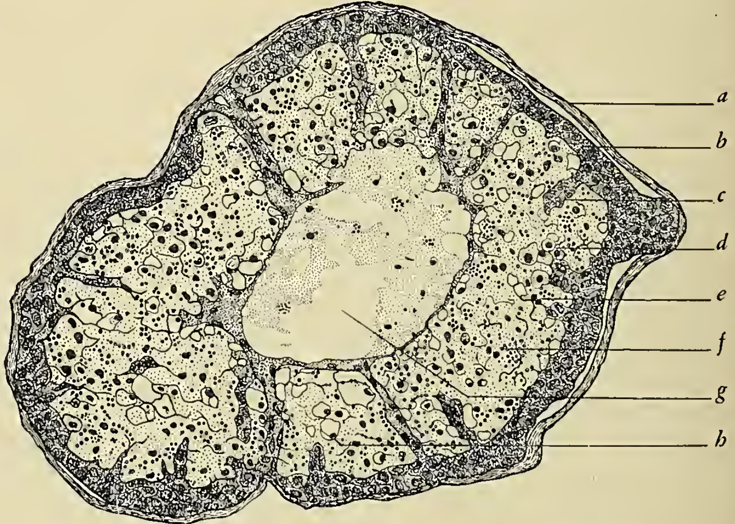

FIG. 5. Camera lucida drawing of a small portion of testis (Fig. 2*e*). *a*, Cumulative tissue; *b*, peripheral layer of epithelium; *c*, Sertoli cells; *d*, primary spermatocytes; *e*, secondary spermatocytes; *f*, spermatids; *g*, central lumen formation; *h*, disintegrating primary spermatocytes. (80×)

geneous mass of primary spermatocytes, in Figure 5 the follicle is filled with a heterogeneous assortment of cells (*d, e, f, h*).

Sections which show the sperm mass in the small collecting tubules are likewise encountered throughout the length of the testis. A longitudinal section of such a tubule (Fig. 6) reveals that a secretion from the epithelium (*b*) also contributes to the continuous sperm mass. Long, fibril-like structures (*c*) are clearly seen, the longitudinal axes of which are parallel to the flow of the sperm mass. The metamorphosing spermatids (*d*) are clumped in rather definite areas and the remainder of the sperm mass (*e*) is scattered indiscriminately. Sections throughout the testis reveal that these tubules coalesce with other similar tubules.

However, sections taken through the regions of the mid-testis (Figs. 2*e*, 3*d*), with the follicles and tubules already referred to, reveal a quite different tube. As indicated by the reconstruction, this tube (Fig. 3*c*) is formed by the juncture of the racemose anterior and posterior portions of the testis, and this highly contorted tube courses throughout a considerable length of the testis (Fig. 3*d*). In many specimens this tube often extends farther posteriorly than anteriorly. Figure 7 represents a cross section through this tube. The greater portion of the epithelium (*f*) is located in glands embedded in the wall of the tube. These glands open into the lumen (*c*) of the tube. The epithelial cells average 43 microns in length and, throughout the entire region, secrete both a mucus-like substance and a granular or crystalline substance (*b*). These "crystals," observed under oil immersion magnification, averaged 1.43 microns in length and were roughly hexagonal. Great masses of these "crystals" (*d*) surround the sperm mass (*e*).

ANATOMY OF THE VAS DEFERENS

Leading from each testis is a highly convoluted tube, the vas deferens (Fig. 1*d*), which,

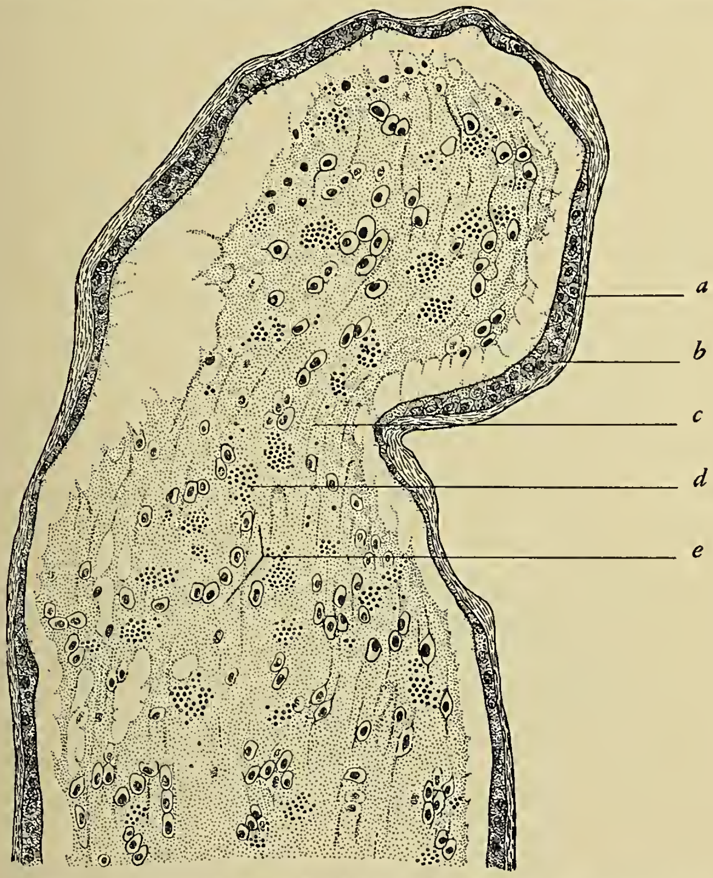

FIG. 6. Camera lucida drawing of a small portion of testis (slightly posterior of Fig. 2*e*) showing tubule in longitudinal section. *a*, Connective tissue; *b*, seminiferous epithelium; *c*, Sertoli fibrils; *d*, developing spermatids; *e*, degenerating primary spermatocytes. (75×)

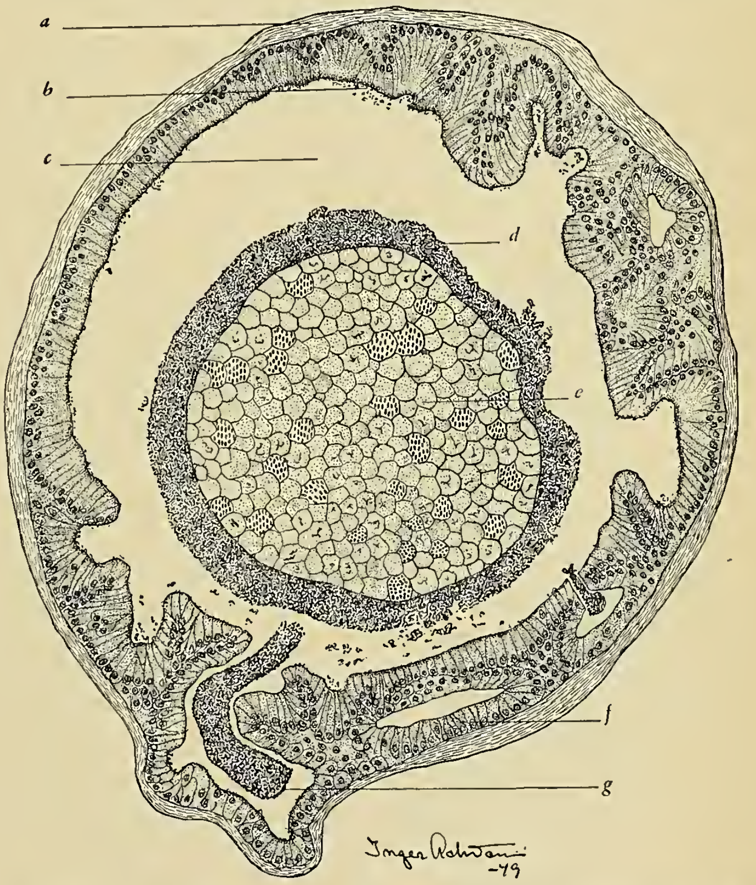

FIG. 7. Camera lucida drawing of a portion of the testis (Fig. 2*c*). *a*, Muscle and underlying connective tissue coats; *b*, crystal-like clumps of material near distal margins of epithelium; *c*, lumen; *d*, wall of spermatophore; *e*, sperm mass; *f*, gland embedded in wall; *g*, spermatophoric wall material exuding from gland. (65×)

increasing in diameter distally, conveys sperm from the testis to the genital pore, located on the coxopodite of the last pereiopod. The proximal portion (Fig. 2*d*), which is impossible to dissect free from the tissue of the testis, emerges to form the enlarged distal portion (Fig. 2*h*). Whereas the testis and certain portions of the vas deferens are opaque, the lateral surface of this enlarged portion of the vas deferens is demarked by a distinct hyaline line (*g*) which traverses its length.

Figure 8 is a typical cross section through the enlarged portion of the vas deferens (Fig. 2*h*). This portion of the vas deferens is characterized by the presence of a typhlosole-like structure (Fig. 8*c*) which projects from the hyaline line (Figs. 2*g*, 8*a*) into the lumen of the vas deferens (Fig. 8*b*). Both the glandular epithelium (*f*) of the "typhlosole," which here bounds deep crypts (*e*), and the connective tissue (*d*) are continuous with the wall of the vas deferens. The wall of the sperm mass (Fig. 7*d*) also appears in sections through the enlarged vas deferens (Fig. 8*g*) but is further embedded in a homogeneous matrix-like substance (*h*). Regardless of the stain used, the glandular secretion (*e*) of the crypt-like folds of the "typhlosole" (*c*) stain the same as the matrix (*h*). Usually, but not in all cases, this secretion takes the cytoplasmic stain.

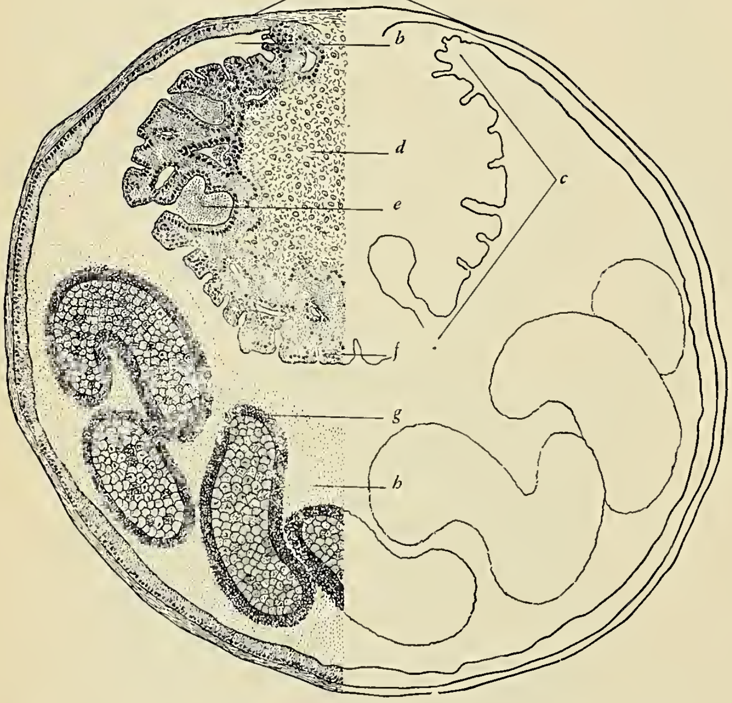

FIG. 8. Camera lucida drawing of a cross section of vas deferens (Fig. 2*h*). *a*, Hyaline line region; *b*, lumen of vas deferens; *c*, "typhlosole"; *d*, connective tissue; *e*, crypt; *f*, glandular epithelium; *g*, spermatophoric wall; *h*, matrix. (13×)

Dissection of the entire enlarged portion of the vas deferens (Fig. 9) along its lateral line reveals, even prior to flattening and fixation, a highly coiled continuous tube (*a*) embedded in a putty-like matrix (*b*). This tube appears as a yellowish "thread" occupying a position near the muscular wall of the vas deferens opposite the hyaline line.

In freshly killed specimens, peristaltic waves traverse the length of this enlarged portion of the vas deferens when it is pinched with forceps. This stimulation is adequate to cause the extrusion of the spermatophoric mass which in nature adheres to the sternum of the female, posterior to the opening of the genital pore.

Figure 10 illustrates a typical spermatophoric mass on a portion of the sternum (*b*) removed from a female whose carapace length was 9.5 cm. and whose carapace width was 7.6 cm. This specimen was taken off Kekepa Island, Oahu, January 23, 1948, by a tangle net set at 30 feet. The ovaries of this specimen were highly developed and ovulation was imminent. The spermatophoric mass, of about average size, was 4.2 cm. at its greatest width, 2.7 cm. at its greatest length, and approximately 0.5 cm. in thickness. The outer, exposed black portion of the mass (*c*) which could not be peeled off had the consistency of whalebone and averaged less than 0.5 mm. in thickness. As in other specimens, the spermatophoric mass displayed a certain bilateral symmetry suggesting that in its application both right and left vas deferens extrude their contents.

Dissection reveals that the homogeneous inner mass, the matrix (*a*), surrounds the highly coiled, continuous, spermatophoric tube (*d*). Lying under the undisturbed portion of the spermatophoric mass (Fig. 10*c*) is found

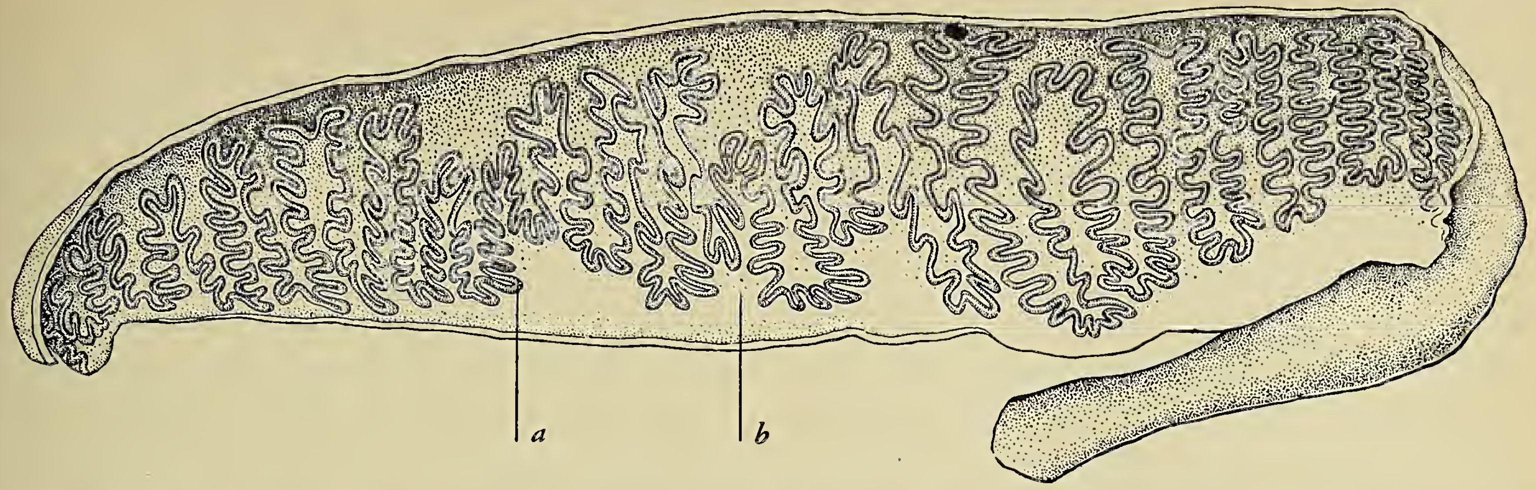

FIG. 9. The enlarged vas deferens dissected along its hyaline line to show: *a*, continuous spermatophore; *b*, region occupied by matrix. (10×)

another continuous spermatophoric tube surrounded by its matrix, products of the opposite or left side of the reproductive system.

DISCUSSION

Since the spermatophoric mass is an accumulation of materials derived from various regions of the male reproductive system, the specific contribution of each region will be discussed in its proper sequence.

By mitotic division, the entire follicle becomes filled with large, primary spermatocytes (Fig. 4*b*). Two processes become evident. From the peripheral layer of the epithelium (Fig. 5*b*) which lies adjacent to the tunica propria (*a*), deeply staining cells (*c*) appear which radiate toward the center of the follicle. At first these are few, some radiating in from one side and some from another. These increase in number without any definite order, creating a wheel-like appearance with the cells forming the "spokes." Care should be exercised in interpreting these early stages because quite often, in sections cut at an angle, these cells appear at the center of the already filled follicle without any relationship to the epithelium from which they arise. Their attached, proximal regions, therefore, would not be evident. Older follicles show these spokes thickened and, at first sight, containing many nuclei. In reality any one spoke is composed of many cells, closely packed together, all radiating toward the center of the follicle. The nuclei, which average 11 microns long and 5 microns wide, are smaller than those of the spermatocyte and more ovoid. These nuclei often appear notched and contain large, deeply staining granules. The reticular, fibrillar nature of the cytoplasm of these cells makes identification of individual cells exceedingly difficult. It should be mentioned that the sections, cut between 5 and 10 microns for routine investigation, are much too thick and too crudely stained for accurate interpretations of the cells. They appear to be Sertoli cells that have actually fused to form a syncytium. This cannot be determined, however, until a more suitable technique is employed.

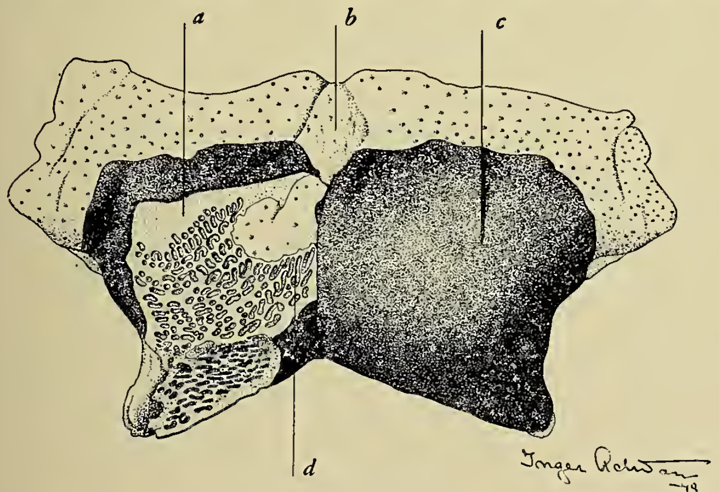

FIG. 10. Spermatophoric mass removed along with a portion of the female's sternum. Right side only dissected to show: *a*, matrix; *b*, sternum; *c*, exposed black portion of mass; d, spermatophoric tube. (1×)

Meanwhile, the second process becomes evident as some of the primary spermatocytes (*d*) undergo two successive divisions, the first probably heterotypic, resulting in two secondary spermatocytes (*e*), and the second homeotypic, which divides the secondary spermatocytes into four spermatids(*f*). Other potential primary spermatocytes fail to complete the spermatogenic process. In these, small vacuoles appear in their cytoplasm, then coalesce to form a large vacuole which surrounds and often pushes the shrunken nucleus to one side of the cytosome (*h*). All stages of cell disintegration may be observed. The contents of disintegrated cells probably serve as nutrient material both during and after the metamorphosis of the spermatids to spermatozoa. If the central lumen (Fig. 5*g*) that forms in the once compact follicle (Fig. 4) is the result of the action of Sertoli cells, it is possible to assume that what appears to be a lumen bounded by a syncytium of Sertoli cells is in reality the distal portions of many Sertoli cells already containing spermatids. Scattered in between these cells is found the debris of disintegrating primary spermatocytes. In any event, the diameter of the lumen increases and the "ring" of Sertoli cells which surrounds the mass moves toward the periphery of the follicle until, finally, only a single layer of epithelium remains.

A longitudinal section of a collecting tubule (Fig. 6) reveals that the epithelium (*b*) in this region appears to contribute a mucus to the continuous sperm mass. Whether this material serves a nutritive or lubricative function was not determined. Long fibrils (*c*), the longitudinal axes of which lie parallel to the flow of the sperm mass, are clearly seen. It should also be pointed out that, whereas the developing spermatids (*d*) clump in rather definite areas, the remainder of the sperm mass (*e*) is scattered indiscriminately. These tubules, which contain the continuous sperm mass, coalesce with other similar tubules until finally, in the mid-region of the testis (Figs. 3*c*, *d*), sections are encountered which possess structures identical with those shown in Figure 7.

When a comparison is made of sections here illustrated by Figures 6 and 7, the presence or absence of a spermatophoric wall (Fig. 7*d*) is not the only significant difference to be seen. The deposition of this wall (Fig. 7*d*) could possibly account for the compactness of the sperm mass, but could scarcely account for the distinct, cell-like membranes which isolate the developing spermatids into distinct clumps. Whereas the longitudinal sections of the collecting tubule (Fig. 6) present the effect of streaming fibrils (*c*), cross sections through the tube (Fig. 7) clearly show these to be portions of Sertoli cells (*e*) cut at right angles to their longitudinal axes. Whether this isolation into clumps of developing spermatids is due to their having been contained within Sertoli cells that have become liberated, or whether the developing spermatids are mechanically isolated by the pressure of the other cells, is difficult to ascertain. It appears very unlikely, however, that the clumping of the developing spermatids is due to an increase in intercellular pressure because these clusters are first observed in sections of follicles where the lumen (Fig. 5*g*) is just forming, and when the pressure would be negligible. The occurrence of spermatid clusters in the region of initial lumen formation strongly suggests that the spermatids in each cluster represent those individuals that develop within a given Sertoli cell, and that, as the Sertoli cell is sloughed off, the contained developing spermatids remain encompassed.

As previously noted, the wall of the spermatophore (Fig. 7*d*) is encountered when the sperm mass of the collecting tubules (Fig. 6) has reached the position indicated by Figure 3*c*. Throughout the length of this highly coiled tube which traverses the testis for some distance both anteriorly and posteriorly (Fig. 3*d*) the glandular epithelium of its wall secretes the material which surrounds and forms the true wall of the spermatophore. Although the thickness of the spermatophoric wall increases as this portion of the tube is traversed, neither the overall diameter of the spermatophore nor the thickness of its wall increases once the walled spermatophore enters the enlarged vas deferens. For this reason, together with the fact that the secretion (Fig. 7*g*) from the epithelium of this tube stains identically with the material (*d*), the deposition of the spermatophoric wall is attributed to this tube.

The walled spermatophore (Fig. 7*d*), upon entering the enlarged vas deferens (Fig. 1*d*), becomes surrounded by a putty-like matrix (Fig. 8*h*) which is formed largely by the secretion from the "typhlosole" (Fig. 8*c*). The position of the walled spermatophoric tube (Fig. 8*g*), embedded in the matrix near the wall opposite the "typhlosole," appears explainable by the fact that, although the glandular epithelium of the peripheral wall of the vas deferens may secrete some matrix, the glandular epithelium of the "typhlosole" secretes most of it, and the extensive production of matrix from this region forces the walled spermatophoric tube toward the periphery of the organ. There is no evidence that the wall of the spermatophore (Fig. 8*g*) is formed by this matrix material. Since the hyaline line (Fig. 2*g*) marks externally the position of the internal "typhlosole," it appears hyaline because the dense matrix between the "typhlosole" and the wall of the vas deferens is here lacking.

Although in nature the actual process of extrusion and adherence of the spermatophoric mass was not observed by the author, the process was experimentally performed for subsequent observation. While immersed in sea water, the vas deferens of a mature male *P. penicillatus* was exposed and pinched with forceps. This served as a sufficient stimulus to cause the extrusion of the spermatophoric mass. This mass was smeared on the sternum of a living female, on a piece of sternum which had been removed from an adult female, and on a clean glass plate. The smeared piece of sternum and the smeared glass plate were suspended by threads in the same aquarium with the artificially smeared female. Within the first hour all the smears darkened slightly, but even after 14 days this darkening had progressed only to a light brown color, the masses never attaining the hardness or the darkness of the spermatophoric mass found deposited naturally. The smear on the isolated pieces of sternum and the smear on the glass plate were eagerly sought after and eaten by the reef fish, *Alectis ciliaris* (Bloch). The smears apparently darkened only superficially, for, when viewed through the glass, the unexposed surface could be seen to retain its putty-like appearance. Attempts were also made by this fish to obtain the smear placed on the living female, but she would quickly retreat to a corner of the aquarium or otherwise protect the mass with the telson of her flexed abdomen. During the 14 days of observation this female made no attempt, however, to remove the mass. At the end of this period, the spermatophoric mass was examined carefully and, except for a few superficial sand scratches, the mass was unaltered. The ovaries were then examined and found to be immature. The spermatozoa, however, in the artificially applied spermatophore were still alive. Although this experiment was repeated several times in an attempt to obtain a female in which ovulation was imminent, all efforts failed. In those mature females which obviously had ovulated, the spermatophoric mass was deeply scratched or gouged, and the spermatophores were devoid of spermatozoa.

Andrews (1931), working on the Oregon crayfish (*Potamobius trowbridgei*), was concerned with the manner of liberation of the spermatozoa and stated: ". . . the suggestion was made by Leuckart that by the gradual change of the wall of the spermatophore, (a secretion from the lining cells of the deferent duct), a discharge of sperms might be caused; but this would need be accurately timed. Very likely, as surmised by Meyer, it is the action of some secretion of the female at the time of laying eggs which induces the emptying of the spermatophore." Andrews mentioned that the spermatophores exhibited free, distinct ends, and their bases were stuck together more or less indistinguishably. The fact that Andrews observed spermatophores over a widely scattered area on the female might possibly be due to the inability of the male to hold fast the female. Since only one case was cited by Andrews, the question arises as to whether this scattering of the spermatophores is the normal manner of application. No mention was made regarding the origin or nature of the adhesive substance, but careful examination of many testis sections of *Potamobius* sp. (prepared commercially by Albert E. Galigher, Inc., Berkeley, California) often reveals a continuous sperm mass enveloped by a spermatophoric wall. Since the developing spermatophore from each testis is in reality a continuous tube, it is possible that the spermatophore in the exuded spermatophoric mass might also be a continuous tube (or two tubes, if each vas deferens contributed simultaneously), as has been shown in *P. penicillatus*. Hurried, intermittent expulsions of the spermatophoric mass by contractions of the muscular vas deferens could account not only for the scattered spermatophoric masses, but also for the formation of the continuous spermatophoric tube into what appears to be separate, distinct spermatophores.

Both Andrews, working with an astacid, the Oregon crayfish, and Herrick (1895), working with the American lobster, a homarid, believe that fertilization is external. On the other hand, von Bonde (1936), working with a palinurid, the Cape crayfish *Jasus lalandii* (Milne Edwards) Ortman, believes fertilization is internal. He describes the condition in *Jasus lalandii* in which the receptaculum seminis of *Homarus americanus* is absent, its counterpart in the position of this structure being only a shallow depression. He further states that this depression is almost covered with hard setae in the living animal and only appears evident in dried specimens, a feature which, he believes, would preclude its use as a receptaculum seminis. The lack of a seminal receptaculum in *Jasus lalandii*, together with the fact that its eggs, when laid, possess an outer membrane of chitin, seem to von Bonde to preclude the possibility of external fertilization and to require that fertilization take place in the oviduct before the chitinous layer is deposited. Moreover, in observations of females after mating and before egg laying, he saw no sign of spermatic fluid on the sternum. Von Bonde concurs with Yonge (1938) that fertilization takes place at the proximal end of the oviduct, and that no difficulty would be encountered by the sperm in achieving fertilization inasmuch as it would need only to penetrate the thin chorion of the egg rather than an outer membrane of chitin. Von Bonde did not explain how impregnation takes place, but it is evident that it is quite different from the manner described herein for another palinurid, genus *Panulirus*.

Crawford and De Smidt (1923) describe the spermatophoric mass for *Panulirus argus* as ". . . composed of two different substances. One substance, which hardens soon after being deposited upon the sternum of the female, forms the bulk and body of the vesicle, while the other substance remains liquid. This liquid does not harden, since it can be expressed when the surface of the vesicle is scraped away. These two substances . . . are probably separated from each other by the process of hardening of the waxy material around the liquid, the pores being formed in a way analogous to the air bubbles in thick glue, or molten glass. . . ." These interpretations are obviously faulty, as demonstrated by my examination of transverse sections of the vas deferens and of the freshly dissected lower portion of this structure.

Wilson (1948), quoting from the unpublished work of Fry (MS.) on the spiny lobster, *P. interruptus*, states, "The presence of putty on the ventral side of a female's carapace is no evidence of maturity as many immature individuals carry sperm. On the other hand, during the breeding season with the exception of a few who had recently cast their shells, no mature female was found which did not have putty or evidence of its former presence." No attempt was made to investigate the contents of the putty-like masses.

The spermatophoric mass on females of *P. penicillatus* which have extruded their ova is deeply scratched; the gouges exhibit a roughened surface and extend through the black, exposed surface, through the matrix, and through the wall of the spermatophoric tube. Figure 10 shows the left side of the spermatophoric mass intact and without deep gouges. When sectioned (right side), the spermatophore contained motile spermatozoa. It should be recalled that this female would probably have discharged her ova presently. Where evidence of the former spermatophoric mass remained, it was deeply gouged, and the exposed, torn spermatophore of both the right and the left side was empty.

Many theories have been advanced for the liberation of spermatozoa from the spermatophore. That the rosette glands of the female's integument may produce a substance which dissolves the capsules of the spermatophoric wall may hold true for the delicate pedunculate spermatophores of the Anomura and Brachyura, but this method of liberating spermatozoa seems very unlikely for *P. penicillatus*. A chemical reaction that would liberate the spermatozoa would have to be exactly timed so that spermatozoa would be available the instant the ova were released. Even so, such action could scarcely have produced the deep, jagged gouges one observes on the spermatophoric mass of *P. penicillatus*. It seems much more reasonable to assume that the spermatozoa are liberated by the scratching action of the female's pereiopods, a method in accord with the observations of Crawford and De Smidt (1923) on *P. argus* and Smith (1948) on *P. interruptus*.

CONCLUSIONS

The H-shaped testis of *Panulirus penicillatus* (Oliver), when reconstructed from serial sections, is found to be a racemose or compound gland of freely branching ducts which terminate in acini. The racemose, anterior portion of the testis joins ultimately the racemose, posterior portion of the testis to form a highly contorted tube. This tube, imbedded in the tissue of the testis, traverses for some distance both anteriorly and posteriorly the region of the mid-testis. Cross sections throughout the entire testis show follicles in various degrees of maturity, although the cells in any one follicle usually exhibit the same stage of development.

The immature follicle becomes filled with potential primary spermatocytes by mitotic division of its seminiferous epithelium. A heterotypic, followed by a homeotypic, division of these cells results in the formation of spermatids. Other potential spermatocytes fail to complete the spermatogenic process, and all stages of disintegration of these cells are observed. Further development within the follicles is attributed to the action of Sertoli cells which, arising from the germinal epithelium, encompass the spermatids. The formation of a lumen, giving the follicle a wheel-like appearance, is attributed to the sloughing off of these Sertoli cells.

Longitudinal sections through the collecting tubules show the sperm mass to be composed of four main components: developing spermatids, disintegrating spermatocytes, a nutrient substance, and portions of sloughed-off Sertoli cells. The evidence of spermatid clusters in the region of initial lumen formation as well as in sections of the collecting tubules strongly suggests that the spermatids in each cluster represent those individuals that develop within a given Sertoli cell.

The continuous sperm mass receives its spermatophoric wall from the tube formed by the juncture of the anterior and posterior racemose portions of the testes. The thickness of this wall increases as this portion of the tube is traversed, but the diameter of the spermatophoric tube remains constant as the enlarged vas deferens is traversed. There is no evidence that the enlarged vas deferens of *Panulirus penicillatus* contributes to the formation of the spermatophoric wall.

The hyaline line of the enlarged vas deferens is associated with a highly glandular typhlosole-like structure. This "typhlosole" produces the bulk of the homogeneous matrix which surrounds the continuous spermatophoric tube. By contraction of the muscular walls of both vas deferens, the spermatophoric mass is exuded.

The spermatophoric mass placed on the sternum of a mature female exhibits a certain bilateral symmetry showing that both the right and left testes and vasa deferentia contribute in its formation. This mass consists of two main components: a continuous, highly convoluted tube—the spermatophore proper —and a putty-like matrix in which the spermatophore is embedded. The spermatophoric mass artificially placed on the sternum of a female hardens and darkens slightly within an hour, but even after 14 days this darkening progresses only to a light brown color, without attaining the hardness or the darkness of the spermatophoric mass found deposited naturally.

Whenever the spermatophoric mass is found scratched or deeply gouged it proves to be devoid of sperm, whereas, if it is found intact, viable sperm are present. Thus, a mechanical method of scratching or gouging the spermatophoric mass for the liberation of the spermatozoa rather than by chemical dissolution is proposed for *Panulirus penicillatus* (Oliver). This method provides ample sperm during ovulation and precludes the probability of internal fertilization.

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The Luminescence of Some Deep-sea Fishes of the Families Gadidae and Macrouridae

YATA HANEDA[1]

INTRODUCTION

WHILE STUDYING THE JAPANESE FISH *Physiculus japonicum* Hilgendorf, of the family Gadidae, Franz (1910) noticed a round black pigmented spot situated ventrally and in front of the anus. He studied its structure, but was unable to explain its physiological function.

Later Kishitani (1930) examined this organ and discovered it was an open type of luminous organ containing symbiotic luminous bacteria. He described its structure and gave a specific name to the bacterium, *Micrococcus physiculus*. He could not see any luminosity while the fish was living under natural conditions, and concluded that the luminous organ merely produced luminous bacteria which were ejected occasionally as a luminous cloud into the surrounding sea water.

In August, 1936, I had an opportunity to observe this fish in the dark in an aquarium tank at the Asamushi Marine Biological Station of Tohoku University. Among many other fishes in the tank, I saw one which I had never seen before, which emitted light from this ventral spot. It did not eject a luminous cloud of matter.

In August, 1937, I observed another species of the Gadidae, *Lotella phycis* Temm. & Schl., which also possessed a similar type of luminous organ, from the duct of which I was able to culture luminous bacteria in artificial media.

The fishes of the family Macrouridae are closely related to the Gadidae and have a luminous organ of the same type. Their luminosity was first recorded by Osorio (1912). One species of the family, *Malacocephalus laevis* (Lowé), has the same type of luminous organ, similarly situated. Osorio stated that it was a practice of the Portuguese fishermen to force luminous matter from the organ by pressing it against pieces of shark flesh which they used as bait. In this way the flesh became luminous, and so was improved as bait for their fishing. This led him to believe that the luminous matter consisted of luminous bacteria, but since he was unable to culture any he could not confirm his belief.

Hickling (1925, 1926) described the structure of the luminous organ of this fish, and stated that it was of a new type, the luminous matter in the organ consisting of luminous granules. In 1931 the same author described the luminous gland of *Coelorhynchus coelorhynchus* Risso, also as a new type of luminous organ containing a luminous granular substance.

Yasaki and Haneda (1936) reported that there were 10 species of the Macrouridae with luminous organs, from the ducts of which they cultured luminous bacteria in artificial media.

In 1938 I examined *Malacocephalus laevis*, described its luminous organ and the contents, and cultivated luminous bacteria from it. Imai (1942) made bacteriological examinations of material from five species of the Macrouridae.

Recently Parr (1946) has studied many macrourid fishes of the western North Atlantic and the Central American seas. He recognized the outer aspect of the luminous organs on the ventral regions of fishes of the genera *Hymenocephalus*, *Malacocephalus*, *Ven-*

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trifossa, *Nezumia*, *Grenurus*, *Trachonurus*, and *Coelorhynchus* as a lens-shaped body, or scaleless "fossa" or naked area.

I have collected and studied the comparative structures of the luminous organs of many specimens of various species, and I have also cultivated their bacteria in artificial media. The results of these observations are presented here.

Acknowledgment: I wish to express my sincere gratitude to Dr. Pletsch, Scientific and Technical Division, ESS, GHQ, SCAP, who helped me in gaining publication of this paper.

MATERIAL

Altogether I have examined material from two species of the Gadidae and 14 species of the Macrouridae.

The Gadidae are comparatively shallow-water fish. They may be caught close to the coast of Japan. *Physiculus japonicus* occurs in water varying in depth from 30 to 50 fathoms. *Lotella phycis* is sometimes taken in extremely shallow water near the surface. This enables one to keep them in an aquarium tank where each can be observed in a natural state. They may be caught at any time of the year by hook and line, and their luminosity may be seen if they are taken during the darkness of the night. *Physiculus japonicus* is occasionally taken by trawlers.

The Macrouridae are always caught by trawlers since they are deep-water fishes living in over 100 fathoms of water. They are taken most abundantly during the winter in Japan.

STRUCTURE OF LUMINOUS ORGANS

Studies made up to the present time show that the Gadidae and Macrouridae possess the same open type of luminous organs. These organs may consist of the following four components: (a) A luminous gland; (b) its canals and their openings; (c) lenses with an external ventral aperture covered with a thin transparent skin through which light is transmitted; and (d) a reflector and chromatophores.

In some species the luminous gland may be so small as to be almost invisible. The canal leading from the gland may be either very short or very long. The structure of the lens may be very complicated, or very simple and inefficient. The reflector may vary also in its efficiency according to its structure.

The external ventral aperture through which light is transmitted is visible externally and may be comparatively large, or very small, or it may be absent. It may be bean-shaped, or circular, or very long and filiform, and in some species there may be two external apertures. The figures illustrate the many forms which can be seen. In the first type the luminous organ is very small and barely visible (as in *Coelorhynchus anatirostris*). It has a very short luminous duct, and is situated very close to the anus lying ventrally in the muscles, and has neither reflector, lens, nor external aperture. The organ cannot be seen externally, and gives the impression that it does not exist. Only when the fish is sectioned longitudinally and a cut is made through the organ can it be seen that there is a luminous duct which is extremely small and inefficient. In this duct are luminous bacteria. Although it is vestigial, it is nevertheless a true luminous organ, difficult as it is to determine.

Coryphenoides garmani and *C. misakius* are two other species which have very short and inefficient luminous ducts. The lenses and external apertures are inefficient, and from a casual inspection it is difficult to say whether they are luminous or not. However, luminous bacteria live in the duct of the gland.

In what may be considered the normal type or the typical luminous organ—such as that found in *Physiculus japonicus*, *Lotella phycis*, *Abyssicola macrochir*, *Coelorhynchus kishinouyei*, *Coelorhynchus japonicus*, and *Nezumia condylura* —the organ consists of a rather large luminous gland, the reflector, the lenses, and a scaleless external aperture covered with thin transparent skin. The canal in some species is rather long and in others very short; for

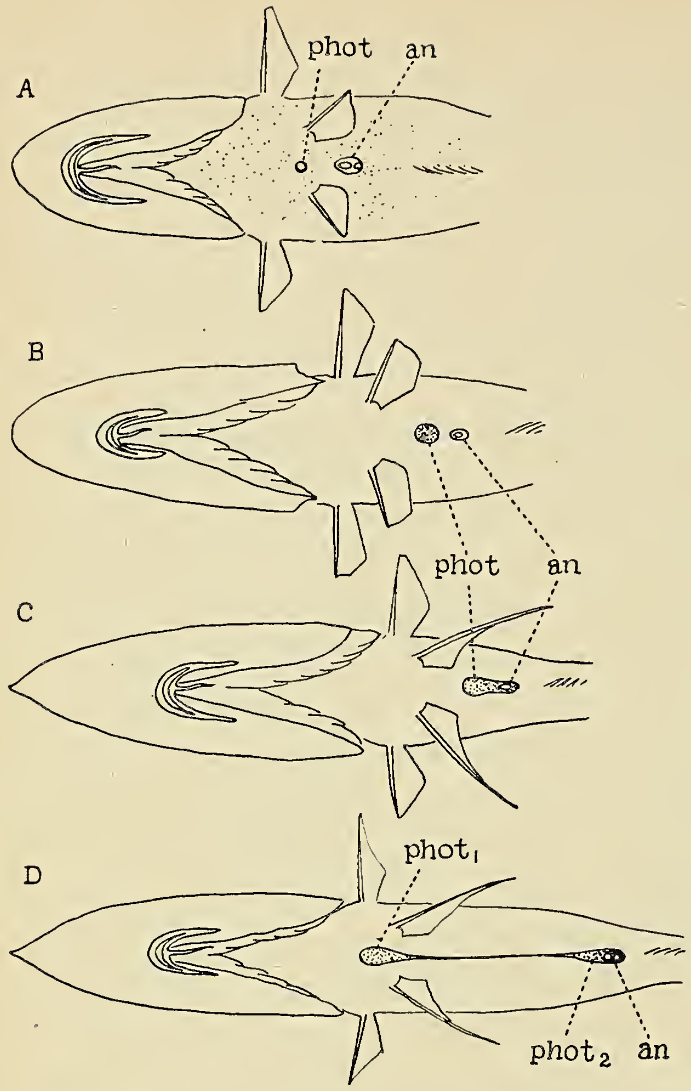

FIG. 1. Diagrams of the luminous organs of some Macrouridae. *a*, *Coryphaenoides garmani; b*, *Abyssicola macrochir; c*, *Coelorhynchus japonicus; d*, *Coelorhynchus hubbsi.* phot, luminous organ; an, anus.

example, *C. japonicus* has a very short canal with the external aperture close to the anus.

Some species have two scaleless external ventral apertures. Examples of this type are *Malacocephalus laevis* (Lowé) and *Malacocephalus nipponensis*, each of which has two external apertures, one bean-shaped and one round. The inner structure is of the normal type, i.e., it has a large luminous gland, a reflector, two lenses, and two external apertures. Their structure has been described by both Dr. Hickling and myself.

The canal is very long in some species, such as *Coelorhynchus parallelus* and *C. tokiensis.* The canal itself functions as a luminous gland with a long reflector, a poor lens substance, and no external aperture. However, one can see the long luminous duct through the transparent scales on the lowest part of the abdomen.

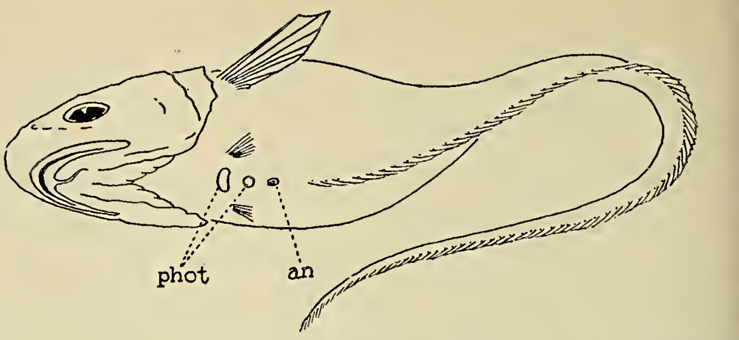

FIG. 2. *Malacocephalus laevis* (Lowé). phot, luminous organ; an, anus.

In their young stages these fishes are very strange, and only in this stage are they strongly luminous, the luminosity being visible ventrally as a single line. When full grown, this thin duct is covered with black pigment, which renders it useless as a luminous component in spite of the fact that luminous bacteria are living within it. The luminosity of *Coelorhynchus coelorhynchus*, as described by Hickling (1931), may be due to the fact that perhaps he saw a young specimen, as it is probable that this species is very similar to the two species under discussion.

Coelorhynchus hubbsi Matsubara has an extremely thin, long canal, each end of which is swollen into a club-shaped gland. The

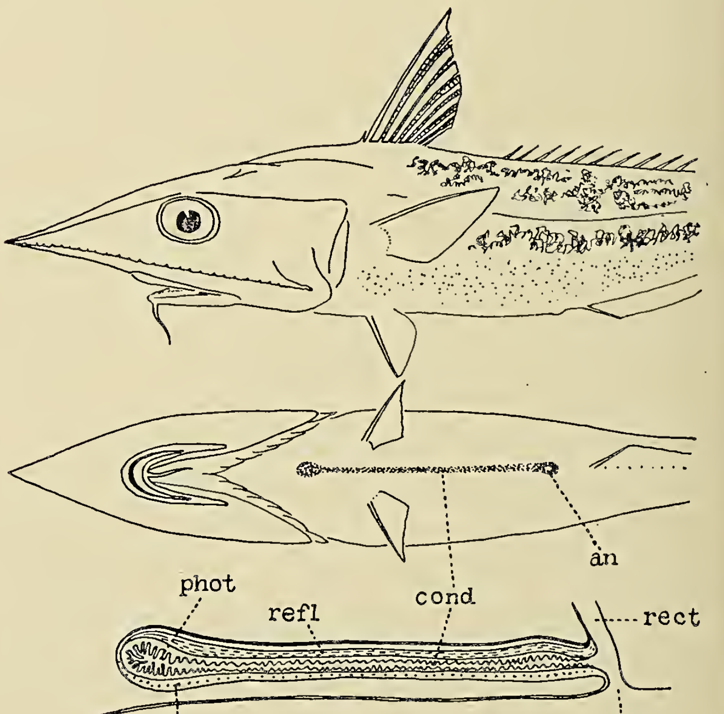

FIG. 3. Diagram of the luminous organ of *Coelorhynchus parallelus* and its longitudinal section. phot, luminous gland; refl, reflector; cond, conduit; chr, chromatophore; an, anus; rect, rectum.

TABLE 1

DATA ON COLLECTIONS OF LUMINOUS GADIDAE AND MACROURIDAE

SPECIES	PLACE OF COLLECTION	DATE OF COLLECTION
Coryphaenoides garmani Jordan and Gilbert Sagami-Sokodara*	Chōshi fish market, Chiba Prefecture.. Mimase fish market, Kōchi Prefecture	Nov., Dec., 1934 Jan., Mar., 1935
Coryphaenoides misakius Jordan and Gilbert Misaki-Sokodara*	Chōshi fish market..................	Nov., Dec., 1934 Jan., Mar., 1935 Jan., 1936
Abyssicola macrochir Günther............. Tenaga-dara*	Chōshi fish market..................	Oct., Nov., Dec., 1934 Feb., Mar., 1935
Coelorhynchus anatirostris Jordan and Gilbert Nezumi-Hige*	Chōshi fish market..................	Nov., Dec., 1934 Feb., 1938
C. japonicus Temm. and Schl.............. Tojin*	Mimase fish market..................	Mar., 1935 Feb., 1938
C. kishinouyei Jordan and Snyder.......... Mugura-hige*	Numazu fish market, Shizuoka Prefecture Heta fishing village, Shizuoka Prefecture	Mar., 1935 Mar., 1938
C. parallelus Günther..................... Soroi-hige*	Mimase fish market..................	Jan., Mar., 1935 Mar., 1938
C. tokiensis Steindachner and Döderlein..... Nezumi*	Mimase fish market..................	Jan., Mar., 1935
C. hubbsi Matsubara..................... Moyō-Hige*	Mimase fish market..................	Nov., 1934 Mar., 1935 Mar., 1938
Nezumia condylura Jordan and Gilbert...... Nezumi-dara*	Chōshi fish market..................	Nov., Dec., 1934 Mar., 1935
Malacocephalus laevis (Lowé).............	Mimase fish market..................	Apr., 1935 Jan., Apr., 1936
Hymenocephalus striatissimus Jordan and Gilbert Suji-dara*	Mimase fish market..................	Apr., 1935 Apr., 1938
H. Kuronumai Kamohara................ Yari-dara*	Mimase fish market..................	Mar., Apr., 1938
H. gracilis Gilbert and Hubbs............ Hoso-suji-dara*	Mimase fish market..................	Mar., Apr., 1938
Physiculus japonicus Hilgendorf............ Chigo-dara*	Mimase fish market.................. Chōshi fish market Asamushi Marine Biological Station, Aomori Prefecture Misaki fish market, Kanagawa Prefecture	Jan., Apr., 1935 Apr., 1937 Aug., 1938 Aug., 1938
Lotella phycis Temm. and Schl............	Misaki Marine Biological Station, Kanagawa Prefecture	Aug., 1938

* Japanese name.

ventral area is scaleless and there are two external apertures. Behind the swelling at the posterior end is a reflector. By examining fresh material in the dark, two luminous points can be seen.

The combination of a very long canal and a compound lens occurs in some species, such as *Hymenocephalus striatissimus* Jordan and Gilbert, *H. gracilis* Gilbert and Hubbs, and *H. kuronumai* Kamohara. In these there is a long, thin canal at the end of which is a club-shaped luminous gland to which is attached, ventrally, a swollen pouch-shaped body. This is a lens. Just behind and below it in the skin of the abdomen is a swelling which is doubly convex. This is a second lens which directs the light ventrally to the outside. It is a very complex organ. This type of luminous organ has already been reported by Vinciguerra (1932).

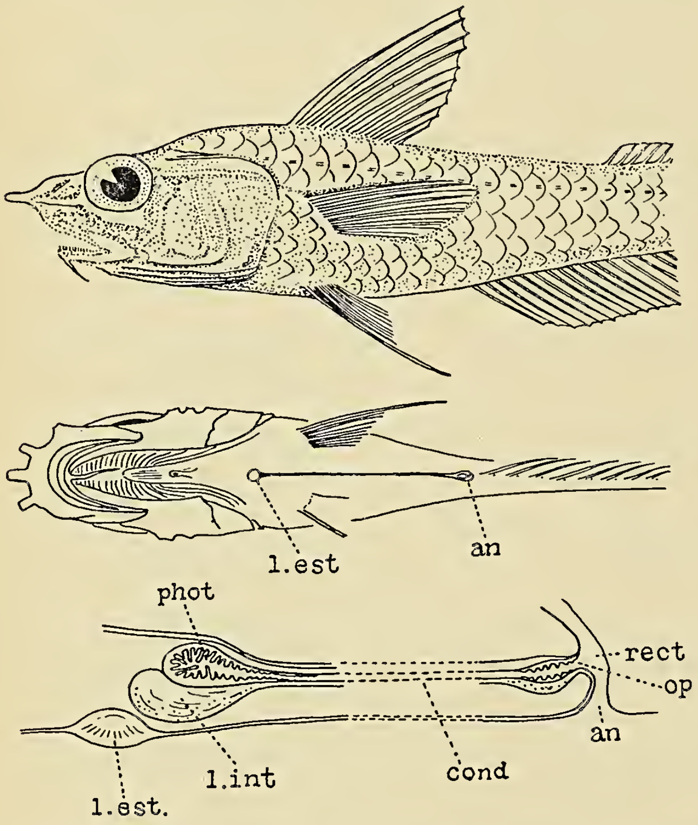

FIG. 4. Diagram of the luminous organ of *Hymenocephalus kuronumai* and its longitudinal section. phot, luminous gland; l.est, external lens; l.int, internal lens; cond, conduit; an, anus; rect, rectum; op, opening of conduit.

All of these are luminous glands and their innermost surfaces are lined with a layer of epithelial cells. Within the cavities formed by the folds of the glands resting on the inner ends of the epithelial cells are other cells which contain capsules in which are masses of bacteria, variously arranged. Some of these capsules are entire and contain the bacteria, others are ruptured and have allowed the bacteria to escape into the fluid of the gland ducts. Hickling says these masses are granules of luminous matter and that they exist in four states, viz.: (a) as closely packed masses filling their capsule; (b) as closely packed masses, but only half filling their capsule; (c) as loosely packed individuals in a ruptured capsule; and (d) as dispersed individuals free from their now empty capsule.

Both Kishitani and I, however, consider these so-called luminous granules to be masses of luminous bacteria. We have examined a great amount of material from many species and it all shows the same characteristics.

LUMINOUS PHENOMENA OF THESE ORGANS WHEN SEEN IN DARKNESS

Inasmuch as *Lotella phycis* and *Physiculus japonicus* live in comparatively shallow water, they can be kept in aquaria where their luminosity, if visible, could be seen in the dark. I have kept many specimens under observation but almost all of them displayed no luminosity which could be seen externally.

In August, 1936, while working at the Asamushi Marine Biological Station, I had a further opportunity to observe these fishes in the dark. Among many specimens of *Physiculus japonicus* in an aquarium tank, I saw one fish with a luminous ventral aperture. This aperture could be seen only when the fish swam upwards and thus showed its ventral surface. It could not be seen when it swam downwards from the top of the tank, showing only its dorsal surface, or when it swam horizontally, showing either one of its lateral surfaces.

I could not see any luminous, cloudy discharge from the opening, as had been suggested, and this led me to believe that the luminosity arose from a true luminous organ, and that the difficulty in seeing it was due to the expansion of the chromatophores in the transparent, scaleless skin which covers the outside of the aperture. When these chromatophores expand they shut off the light and when they contract the light is transmitted and can be seen. Possibly the expansion and contraction may be determined by the water temperature, the degree of darkness or light, or by other factors, but I did not determine the effects of these factors upon the functioning of the chromatophores.

However, from my observations I am of the opinion that when these fishes are swimming in natural conditions at the bottom of the sea they are normally luminous, emitting light through these ventral apertures.

I have never been able to observe any macrourid fish in a natural condition since they are all deep-sea fish and cannot be kept in an aquarium. I have been able to examine only dead and living material freshly caught by trawlers from deep water. When examining this freshly caught material I could see the luminosity of some, but not of others. When the glands were cut open, however, they were always luminous.

The luminosity of young *Coelorhynchus parallelus* may be seen as a beautiful green filiform line on the ventral surface. *Coelorhynchus hubbsi* has two luminous spots on the ventral surface, and I am of the opinion that these fishes, when in their natural conditions, normally display their luminosity.

I cannot agree with the opinion that these fishes, through the opening of the canal in the anal region, discharge a luminous cloud into the surrounding sea water.

CONTENTS OF THE LUMINOUS DUCTS

Emulsions of the contents of the ducts were made in sterile sea water and were examined in the dark.

When first made, the emulsion was uniformly luminous. After standing in vertical tubes and settling for 20 minutes, the luminosity had collected as an upper layer. When shaken up, it was again uniformly distributed in the tube. If it was centrifuged, the luminosity was concentrated in the sediment at the bottom of the tube and the fluid above was clear and not luminous. If this precipitate was well mixed with sterile sea water the whole mixture became uniformly luminous, but if it was mixed with sterile distilled water, it failed to show any luminosity.

Changes of temperature showed the following results. Luminosity was greatest between 15 and 23°C. and this is the optimum temperature; at 0° C. it ceased; at 3–4° C. it was very weak; at temperatures between 23° and 45° C. it decreased; above this point it finally ceased and could not be reactivated when cooled again to 15–23° C.

The reactions were those of luminous bacteria and an examination under the microscope showed bacteria and segments of the gland duct cells. The bacteria stained red with Ziehl's solution and I was able to culture them by the usual bacteriological methods. Samples were taken from the organs of every fish studied. The characteristics of the luminous bacteria from the luminous ducts of many species of fishes of the Gadidae and the Macrouridae were investigated by the usual methods of culture in artificial media.

I was able to obtain 10 strains of luminous bacteria from each of these fishes—*Lotella phycis*, *Malacocephalus laevis*, *Hymenocephalus gracilis;* 20 strains of luminous bacteria from *Coelorhynchus kishinouyei* and *Nezumia condylura;* and 14 strains from the other species.

These strains of bacteria were taken from various species of fish taken at different times and in different localities. All had the same general biological characters but the optimum temperature, that is, the temperature at which the luminosity was greatest, varied. In some cases it was higher than others, but it never varied much. The optimum temperature for luminosity was lower for the bacteria of those fishes which live in deep and therefore colder water than for those living in the shallower and warmer water. A more complete discussion of these bacteria will be presented in a separate paper.

SUMMARY

Some of the fishes belonging to the families Gadidae and Macrouridae are luminous and possess the "open type" of luminous organ containing luminous symbiotic bacteria. It consists of a gland in the ventral muscles lying in a scaleless depression between the pelvic fins. This is a characteristic of these fishes. Their luminescence is controlled by means of chromatophores. Normally they are deep-sea fishes although at times some of the Gadidae may be caught in shallow water. Observations were made on 14 species of the Macrouridae and 2 species of the Gadidae. Their luminous ducts are very similar but vary in size. In some species they are very long, in others very short, and in others extremely small and not visible from the outside. Some of the luminous ducts are of a comparatively simple construction while others are extremely complex.

I consider the luminous symbiotic bacteria which were cultured from these many fishes to be a species of the new group of luminous bacteria, but a more complete discussion will be presented later in a separate paper.

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Fabricinae (Feather-duster Polychaetous Annelids) in the Pacific[1]

OLGA HARTMAN[2]

THE UPPER LAYERS of mud in tidal basins such as sloughs and lagoons of various parts of the world are often abundantly populated by minute worms of widely related annelids, for example, *Streblospio benedicti* Webster of the family Spionidae, *Capitella capitata* (Fabricius) of the family Capitellidae, and several species of Sabellidae, subfamily Fabricinae, discussed below. Estuarine worms of this kind may occur in prodigious numbers over considerable areas. Since they are usually very small (a few millimeters long), inconspicuously colored, and covered with slime and debris, they are easily overlooked. Because of their abundance and slime-secreting properties they may be a factor of considerable importance in preventing soil transport.

The Fabricinae are known from the Pacific from comparatively few, mostly isolated, records. The present study concerns some unreported populations from California. In addition, other species of the subfamily from the Pacific are reviewed, and affinities of some others indicated. *Monroika*, a new name, is proposed for *Manayunkia africana* Monro, 1939. There are new combinations in the genera *Fabricia*, *Oridia*, and *Manayunkia*. *Fabricia limnicola* is newly described. The illustrations on the plate were prepared by Mr. Anker Petersen, staff artist of the Allan Hancock Foundation.

The family Sabellidae Malmgren comprises the subfamilies Sabellinae, with 16 to 18 genera and well over 100 species, Fabricinae (below), Myxicolinae, with a single genus and about 7 species, and Lamellisabellinae, an aberrant, controversial category[3] known for a single species, *Lamellisabella zachsi* Uschakow, from the northwest Pacific.

The last named species is known through a single collection from the southern end of the Okhotsk Sea taken at 3,500 meters in gray-green mud (Uschakow, 1933: 205–208, 2 figs.). A more complete description based on some of the same material is that by Johansson (1937: 23–26, 4 figs.) and the most recent discussion is by Ulrich (1950: 1–25). Uschakow regarded the species as an aberrant sabellid and erected for it the subfamily Lamellisabellinae. Johansson made anatomical studies and concluded that the original account mistook dorsal for ventral sides. The originally named ventral collar thus became the head, or prostomium, with the contained central nervous system. The name Pogonofora was proposed for a new class of organism. Ulrich reviewed the previous accounts, and concluded that the species is even more remote from the annelids than previously supposed; he placed Pogonofora between Tentaculata and Enteropneusta.

The available evidence is not yet convincing. Especially noteworthy is the fact that no one has ever seen the mouth. What was presumed to be the brain in the collar lobe may represent a giant suboesophageal ganglion; the true brain and prostomium may lie well concealed by the tentacular crown. In some slender sabellids, these parts are difficult to see unless the tentacular crown is removed or specimens are fixed after removal from the tube.

The major objections to regarding *Lamel-*

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[1] Contribution No. 74 of the Allan Hancock Foundation. Manuscript received August 11, 1950.

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[3] A recent communication from Professor J. P. Moore, University of Pennsylvania, Philadelphia, Pa., has expressed a similar view with regard to *Lamellisabella zachsi* Uschakow.

lisabella as a polychaete are the supposed absence of setae (which may, however, be represented by the chitinized platelets); the absence of a dorsal groove (which is present if the collar is ventral); and the scarcity of dissepiments (though this scarcity is known for some other annelids). Strong evidence for Uschakow's view is the high palmate membrane of the crown, the body form, the well-developed thoracic collar, the posterior anus, the segmentally arranged parapodial-like structure, and the uncinial-like structures.

The subfamily Fabricinae Rioja, 1917, includes more than 60 species in 12 or more genera. Unlike members of the Sabellinae, which are often very large and conspicuously colored, the Fabricinae are usually minute (only a few millimeters long), but some of the *Chone* group, such as *Megachone aurantiaca* Johnson, are large (more than 80 millimeters long).

The Fabricinae are remarkable for their adaptability to varying intertidal conditions and their adjustment to either brackish or fresh water. The term "sedentary" is not altogether appropriate since many species construct transitory tubes that are rebuilt after removal. Locomotion is forward or backward. The most nearly related species in such genera as *Fabricia* and *Manayunkia* may have interrupted distributions in widely scattered fresh-water regions and intertidal zones (see below).

In their morphological characters the Fabricinae are sometimes separable only microscopically from some smaller members of the Sabellinae. The most reliable and practical character concerns the structure of thoracic neuropodial hooks: in the Fabricinae they are long-handled (Fig. 3); in the Sabellinae they are avicular, lacking a handle. In the first, the nephridial apertures may open only at the anterior end of the thorax, mid-dorsally near the peristomium (hence the name Thoracogoneata Zenkewitsch, 1925); in the second, the nephridial apertures are present in thorax and abdomen (the Abdominogoneata of Zenkewitsch, 1925). In the Fabricinae, the muscular tissue is nematoid (Johansson, 1927); in the Sabellinae it is not nematoid. In the first there are pulsating pouches (Fig. 1), sometimes called branchial hearts, in the peristomium; in the second such pouches are lacking.

The Fabricinae are recognizable for 12 genera including one (Monroika) newly proposed for an aberrant fresh-water species from the Congo River, Africa (see below). There are other described species, such as *Haplobranchus balticus* Karling, 1933, from Finland, and *Fabricia alata* Ehlers, 1897, from Patagonia, that are not clearly referrable to known genera. These 12 genera, with their Pacific representatives, are as follows:

1. *Caobangia* Giard, 1893, is known for a single small species, *C. billeti* Giard, 1893, from Tonkin, French Indo-China, in fresh water. See Monro (1939: 232) for review.
2. *Chone* Kröyer, 1856, is known for about 20 species, all marine, with the following 6 from the Pacific:
   - *C. cincta* Zachs (1933: 135) from the north Japan Sea.
   - *C. ecaudata* (Moore), 1923, from California. See Hartman (1942: 135–136, figs. e–g).
   - *C. gracilis* Moore (1906: 257–259, figs. 62–66), from Alaska.
   - *C. infundibuliformis* Kröyer, 1856, from Arctic and boreal seas of both hemispheres. See Fauvel (1927: 334–335, fig. 116).
   - *C. minuta* Hartman (1944: 280–281, figs. 50–52, 59–60), from California.
   - *C. mollis* (Bush), 1904, from California. See Hartman (1944: 279–280, figs. 47–49).

   Nine of the remaining species are known from northern and western Europe, two are from the tropical east Atlantic, two are from the Arctic Ocean, one is from northeast America, and one is from South Africa.

3. *Dialychone* Claparède, 1870, is known for a single species, *D. acustica* Claparède, from the Mediterranean Sea. See Fauvel (1927: 333, fig. 115).
4. *Euchone* Malmgren, 1866, is known for about 13 species, all marine, with the following 5 from the Pacific.
   - *E. alicaudata* Moore and Bush (1904: 165–167), from Sagami Bay, Japan.
   - *E. analis* (Kröyer), 1856, from Greenland and the northeast Pacific. See Berkeley and Berkeley (1942: 206).
   - *E. magna* Moore (1923: 245–246), from southern California.
   - *E. olegi* Zachs (1933: 135), from the north Japan Sea. See Annenkova (1938: 215) for review.
   - *E. papillosa* (Sars), 1851, from Finmark and north Japan Sea. See Annenkova (1938: 215).

   In addition, two species are from New England and eastern Canada, one is from Greenland and the north Atlantic Ocean, one is from the British Isles, two are from Spitzberg and Norway, one is from the tropical east Atlantic, and one is from the Kerguelen Islands.
5. *Fabricia* Blainville, 1828, is known for eight or nine species, in brackish to marine seas, with five or six species from the Pacific.
   - *F. dubia* Wesenberg-Lund, 1941, from the northeast Pacific (see below).
   - *F. limnicola*, new species, from California (see below).
   - *F. pacifica* Berkeley and Berkeley, 1950, from western Canada (see below).
   - *F. ventrilinguata* Johansson, 1922, from Japan (see below).
   - *F. sabella* (Ehrenberg), Annenkova (1938: 214) from the north Japan Sea.
   - ?*F. siaukhu* (Annenkova), 1938, from the north Japan Sea (see below).

   In addition, the following species are discussed below: *F. atlantica* (Treadwell), *F. capensis* (Monro), *F. dubia* Wesenberg-Lund, *F. leidyi* Verrill, and *F. alata* Ehlers, which is very questionably a member of this genus.
6. *Jasmineira* Langerhans, 1880, is known for 10 species, all marine, of which one is found in the Pacific.
   - *J. pacifica* Annenkova (1937: 195–196, 3 figs.), from northeast Asia.

   In addition, one comes from Spitzberg, three are from western and southern Europe, two are from the Kerguelen Islands, one is from southwest Africa, one is from Ceylon, and one is from the Antarctic.
7. *Manayunkia* Leidy, 1858, is known for possibly nine species, in fresh water to brackish or marine; one is in the Pacific.
   - *M. pacifica* Annenkova (1934: 329–330, fig. 10), from Bering Island.

   In addition, others from various parts of the world are discussed below.
8. *Megachone* Johnson, 1901, is known for a single marine species, from the Pacific.
   - *M. aurantiaca* Johnson (1901: 430–431, figs. 186–192), from Washington.
9. *Oridia* Rioja, 1917, is known for seven or more species, all marine, of which four are from the Pacific.
   - *O. armandi* (Claparède), 1864, from southern Europe, is reported from western Mexico. See Rioja (1941: 732, pl. 9, figs. 9–10).
   - *O. crenicollis* Annenkova (1934: 330–331, fig. 11), from the Bering Sea.
   - *O. minuta* (Berkeley and Berkeley), new combination (see below).
   - *O. rivularis* Annenkova (1929: 119–122, figs. 1–7), from the Sea of Okhotsk, eastern Asia.

   In addition, another is known from western Europe, one is from Patagonia, and one is from South Africa.
10. *Oriopsis* Caullery and Mesnil, 1896, is known for a single marine species.
    - *O. metchnikowi* Caullery and Mesnil, 1896, from Europe. See Fauvel (1927: 328–330, fig. 114).
11. *Potamethus* Chamberlin, 1919, is known

for five species, all marine, of which two are from the Pacific.

P. elongatus (Treadwell) (1906: 1178, figs. 73–75), from off Molokai Island. See Hartman (1942: 134–135, figs. *b–d*), for emendation.

P. mucronatus (Moore) (1923: 243–245, figs. 43–44), from southern California. See Hartman (1942: 134, figs. *a*, *h–j*) for review.

In addition, single species come from deep water off Florida and Norway, and from the Antarctic Ocean.

12. *Monroika*, a new name, is proposed for a single aberrant fresh-water species, *M. africana* (Monro), 1939, from the Congo River (see below).

KEY TO GENERA AND PACIFIC SPECIES OF FABRICINAE

1. Thoracic neuropodia with long-handled uncini accompanied by pennoned setae (Hartman, 1942, fig. *i*) ...... *Potamethus* 12
1. Thoracic neuropodia lack pennoned setae 2

2. Tentacular radioles free, without a weblike or palmate membrane 3
2. Tentacular radioles united for some distance by a weblike membrane .. 9

3. First setigerous segment with palmate and slender setae; alimentary tract recurved so that anus is anteroventral; first 7 setigers lack ventral uncini .... *Caobangia*
3. Palmate setae absent; anus opens posteriorly 4

4. Tentacular radioles vary in length; abdomen with 60 or more segments .... *Dialychone*
4. Tentacular radioles otherwise; abdomen with few to many segments .. 5

5. Abdomen with many segments; thoracic collar well developed and bilobed .... *Jasmineira pacifica*
5. Abdomen with few segments or a limited number 6

6. Radioles unbranched .... *Manayunkia* 13
6. Radioles branched in pinnate arrangement 7

7. With 7 thoracic setigerous segments .... *Oriopsis*
7. With 8 (except in *Fabricia ventrilinguata*) thoracic setigerous segments 8

8. Abdominal uncini with long handle (Fig. 5); abdomen usually with 3 segments (Fig. 2) .... *Fabricia* 17
8. Abdominal uncini avicular or short handled; abdominal segments 3 to 5 or more .... *Oridia* 21

9. Abdomen with a deep ventral groove at posterior end of body .... *Euchone* 25
9. Abdomen without such groove at posterior end of the body 10

10. Tentacular radioles are simple unbranched filaments .... *Monroika africana*
10. Tentacular radioles have pinnately arranged filaments 11

11. Some thoracic notopodial setae broad and spatulate .... *Chone* 27
11. Broad spatulate setae absent .... *Megachone aurantiaca*

12. Thoracic collar oblique; thoracic spatulate setae with a short mucro .... *Potamethus mucronatus*
12. Thoracic collar nearly straight; thoracic spatulate setae with a long mucro .... *Potamethus elongatus*

13. With few tentacular radioles 14
13. With many, 16 or more, pairs of tentacular radioles 15

14. With 4 pairs of radioles .... *Manayunkia estuarina* and *M. polaris*
14. With 6 pairs of radioles .... *Manayunkia caspica*

15. With 16 to 20 pairs of tentacular radioles 16
15. With 24 to 36 pairs of tentacular radioles .... *Manayunkia baicalensis*

16. Without peristomial or pygidial eyes .... *Manayunkia speciosa*
16. With peristomial and pygidial eyes.. .*Manayunkia pacifica* and *M. spongicola*

17. Thorax with only 4 setigerous segments.......... *Fabricia ventrilinguata*
17. Thorax with 8 setigerous segments.. 18

18. Thoracic collar only ventral and limited; thoracic notosetae include slender and spatulate ones...... 18*a*
   a. Radioles number presumably 2 pairs............... *Fabricia atlantica*
   b. Radioles number 3 pairs........ .... *Fabricia dubia*
18. Thoracic collar more extensive and with straight margin; thoracic notosetae slender (Fig. 7) to subspatulate.......................... 19
18. Thoracic collar with festooned fringes .... ?*Fabricia siaukhu*

19. Thoracic collar presumably absent.. .... *Fabricia leidyi*
19. Thoracic collar present............. 20

20. Collar with a pair of digitate lobes at the middorsum....... *Fabricia capensis*
20. Collar without digitate lobes at the middorsum......... *Fabricia limnicola*

21. Thoracic collar with a crenulate margin................. *Oridia crenicollis*
21. Thoracic collar with a straight margin. 22

22. Pygidial eyes (Fig. 2) present....... 23
22. Pygidial eyes absent............... 24

23. Thoracic setae include spatulate and slender ones........... *Oridia minuta*
23. Thoracic setae include only slender ones................. *Oridia armandi*

24. Thoracic setae include spatulate and slender ones.......... *Oridia rivularis*
24. Thoracic setae include only slender ones................. *Oridia limbata*

25. Thoracic spatulate setae lack a mucro .... *Euchone magna*
25. Thoracic setae with a mucro or slender point.......................... 26

26. Thoracic collar oblique and longest dorsally........... *Euchone alicaudata*
26. Thoracic collar about equally high all around............... *Euchone analis*

27. Thoracic spatulate setae nearly to without a mucro; body larger, 50 to 100 mm. long................ 28
27. Thoracic spatulate setae with a mucro; body smaller, less than 40 mm. long.......................... 29

28. Spatulate setae with a short mucro; color in life pale rose or green.... .... *Chone infundibuliformis*
28. Spatulate setae without a mucro; color in life white or pale yellow....... .... *Chone mollis*

29. Abdomen with 17 or 18 segments; spatulate setae with a short mucro; radioles number 7 to 9 pairs...... .... *Chone ecaudata*
29. Abdomen with about 26 segments; spatulate setae with a moderately long mucro; radioles number 6 or 7 pairs................. *Chone minuta*
29. Abdomen with about 51 segments; spatulate setae with a very long mucro; radioles number about 10 pairs.................. *Chone gracilis*

Genus FABRICIA Blainville, 1828

This genus was recently re-examined and emended by Berkeley and Berkeley (1950) to include the characters of *Oridia* Rioja (1917). I prefer herein to restrict *Fabricia* to exclude *Oridia*, but to support Berkeley's opinion regarding the lack of importance of thoracic collar development. The diagnosis of the genus is thus the same as that proposed by Berkeley and Berkeley (1950: 66) except that in *Fabricia* the abdominal uncini are long handled and the distal cutting edge has pectinately arranged teeth (Fig. 5), whereas in *Oridia* the abdominal uncini are avicular, lacking a handle.

The generic diagnosis may be summarized. The body consists of the peristomium followed by eight (only four in *F. ventrilinguata* Johansson) thoracic and three abdominal setigerous segments and a pygidium. The tentacular crown has two or three (Fig. 2) pairs of radioles with filaments in pinnate arrangement; there are no stylodes or radiolar eyes. The palpi are paired and filamentous (Fig. 2). Eyes (Fig. 2) are present in peristomium and pygidium, or one or both pairs are lacking. The thoracic collar is absent, or developed to a varying degree. The first segment lacks setae; the second segment has notosetae only, all of them slender and distally pointed. Segments 3 to 8 (or only 3 to 5) have pointed setae in notopodia; they are slender and narrowly to broadly limbate. Neuropodia have long-handled uncini (Fig. 3). Abdominal segments have pointed setae in neuropodia and long-handled uncini (Fig. 5) in notopodia, with teeth in pectinate arrangement.

The genotype, *F. sabella* (Ehrenberg), has peristomial and pygidial eyes; a thoracic collar is nearly absent; the tentacular crown has three pairs of radioles, and the pinnately arranged filaments are in double rows.

Fabricia limnicola new species

Plate 1, Figs. 1–9

COLLECTIONS: Many individuals come from estuarine, intertidal mud flats of Newport Bay and Anaheim Slough, southern California.

The body is threadlike except for the spreading tentacular crown; total length is 5 to 7 mm. or less; width is ½ mm. or less. Color in life and preserved is pale translucent to white. The body consists of the crown, a simple peristomial ring, eight thoracic and three abdominal setigerous segments, followed by a triangular pygidium.

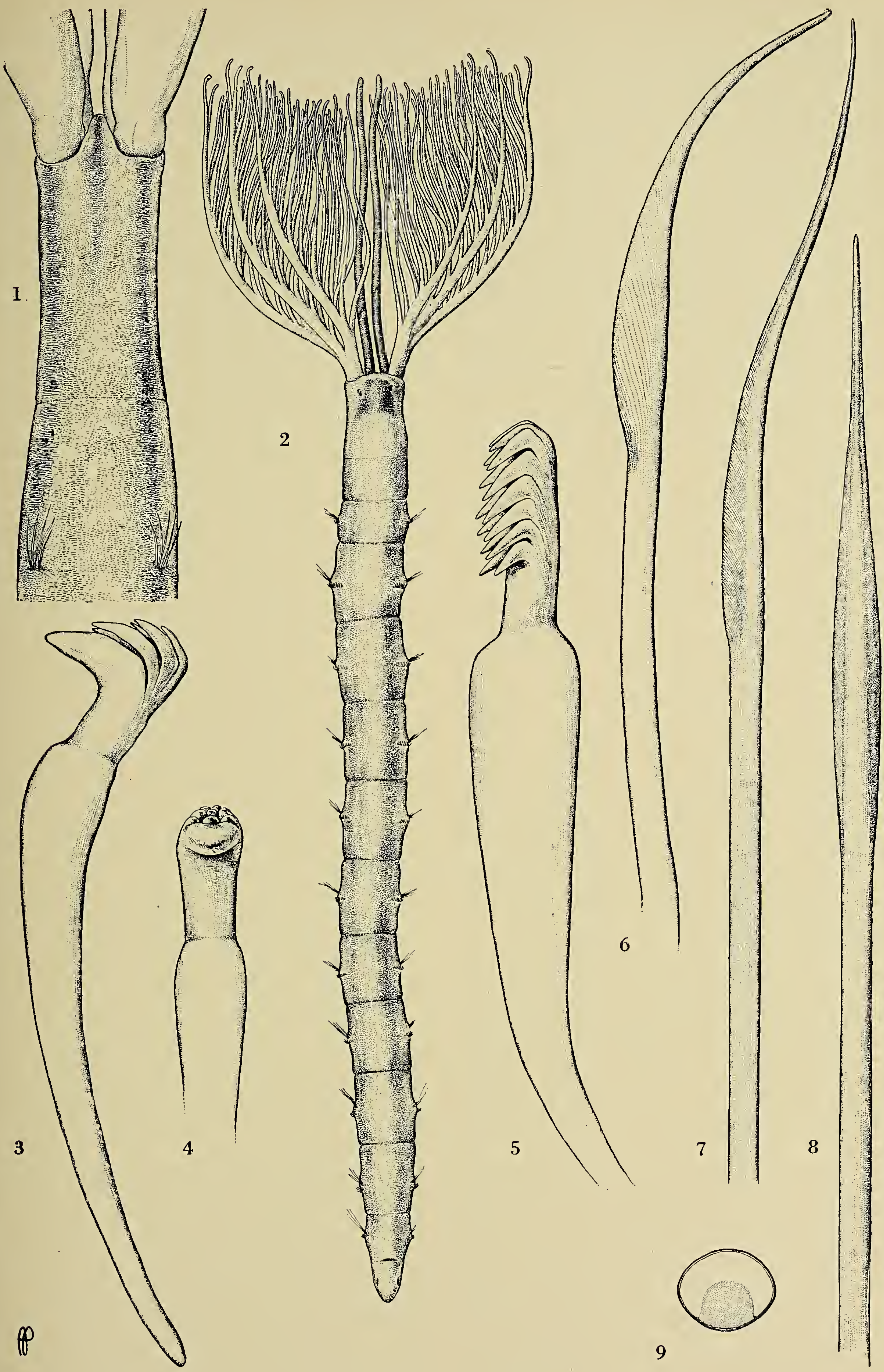
The tentacular crown consists of paired, symmetrical halves with semicircular bases. Each half has three long radioles, lacking a weblike membrane. Each radiole has 6 or 7 to 8 or 10 double rows of slender filaments that rise from the inner lateral side of the radioles; successive filaments rise from different levels but all extend distally about equally far. The total number of filaments for a larger specimen may be 72 to 100. The distal free ends of the radioles are long and smooth (Fig. 2). The paired palpi are long, slender, and dusky in color, and extend distally as far as, or somewhat beyond, the radiolar tips. The prostomium is bluntly rounded to conical; it extends forward so as to be slightly visible beyond the thoracic collar (to be seen when the tentacular crown is removed), or it is less long and fully concealed.

The thoracic collar is a high, straight membrane, continuous all around except for a dorsal fusion with the upper side of the prostomium (Fig. 1); it is closely appressed to the base of the tentacular crown around its lateral and ventral parts and may be overlooked as a separate collar membrane except when the tentacular crown is removed.

The first segment, or peristomium, is longer than those following (Fig. 2); it is longer in specimens fixed in the tube than in those out of it. On its ventral side is a quadrangular, dark area, broadest at its posterior margin; it marks the position of the oral aperture within the collar and is thus between prostomium and peristomium. Dark eyespots are present on the peristomium, visible when the collar is pushed aside.

The second or first setigerous segment is shorter than the peristomium and shorter to longer than those following. It is plain except for the notosetal fascicle which carries from five to eight slender, pointed setae.

PLATE 1. *Fabricia limnicola*. 1, Anterior end showing base of tentacular crown and first two segments, dorsal view, ×66; 2, entire animal with expanded tentacular crown, ventral view, ×37; 3, thoracic neuropodial hook, side view, ×1580; 4, distal end of thoracic neuropodial hook, front view, ×1580; 5, abdominal notopodial hook, side view, ×1705; 6, short thoracic notopodial seta, side view, ×2350; 7, long thoracic notopodial seta, side view, ×1620; 8, long thoracic notopodial seta, back view, ×1620; 9, cross section of thoracic notoseta from widest region, showing core below and expanded region above, ×3240.



Setigerous segments 2 to 8 are biramous. Each notopodium has seven to nine pointed setae and five to eight long-handled uncini arranged in transverse series.

The abdomen consists of three setigerous segments followed by a short, tapering, slightly depressed pygidium, with a pair of dark eyespots located near the posterior end and lateral. The anal aperture is on the ventral side, a short distance in front of the eyes but median. It is followed by a short triangular lobe tapering distally. The proportions and locations of these parts are shown in Figure 2.

Thoracic notosetae are of two kinds. The first three segments have fascicles of eight or nine each; these setae are long, slender, and distally pointed (Figs. 7, 8). Although they appear winged or bilimbate, the distal broad flange is thickened all around the stalk, as can be seen in cross section at the thickest or broadest part of the seta (Fig. 9). Similar setae are present in all other thoracic segments. Beginning at the fourth one and continuing in other thoracic segments, there are only five or six of the longer setae and the lower ones are replaced by three or four shorter, broader ones (Fig. 6). Thoracic uncini are long handled and of a single kind (Fig. 3). They number 7 to 9 or 11 in single transverse series. Each uncinus is slightly beaked and has a large fang and several rows of smaller teeth (Fig. 4).

Abdominal parapodia are biramous. Notopodia are slightly elevated, transversely elongated, and have a single row of handled uncini that number 20 to 30 in a single series; the greatest number in a row is in the first segment and the least in the third segment. The largest uncini in a single series are at the inferior end of the row and there is a gradual diminution in size going upward. These uncini have a double row of seven or eight teeth in pectinate arrangement (Fig. 5). In normal position in parapodia, the tips of the teeth are directed outward and forward. In slide preparations the individual uncini are likely to have handles or teeth imperfect or broken. This fact, together with their small size (less than 20 micra for the length of the distal part beyond the thickened shoulder), doubtless accounts for imperfect or variable descriptions of abdominal uncini in the different descriptions of species in the genus *Fabricia*.

Some of the specimens examined have many small spherical ova, crowded in thoracic setigerous segments 5 to 9. The only color visible in living or preserved individuals is limited to a few regions. There is a dusky area on the ventral side of the collar and peristomium; a similar pigment is on the dorsal side marking the notch of the collar; the prostomial cone and the palpi are dusky; the eyespots in the peristomium and pygidium are dark, and setae are pale yellow.

The tube is constructed of uniformly small, agglutinated sand granules; it adheres closely to the occupant so that specimens fixed in the tube are difficult to remove. In life, removal can be effected by application of a drop of toxic fluid at the end of the tube.

Holotype and other specimens are deposited in the Allan Hancock Foundation of the University of Southern California, Los Angeles, California.

DISTRIBUTION: Southern California, in estuarine marine mud flats.

Fabricia dubia Wesenberg-Lund

Fabricia sabella Berkeley, 1930, fig. 1g only.
Fabricia dubia Wesenberg-Lund (1941: 33–35, figs. 2–4).

COLLECTIONS: Many specimens come from South Bay in Coos Bay, Oregon, washed from intertidal rocks, August, 1950 (coll. Donald Reish).

Individuals measure 2 to 3 mm. long and 0.26 mm. across. There are eight thoracic and three abdominal setigerous segments; the last five thoracic segments are much the longest. The tentacular crown consists of three pairs of radioles, each having many paired filaments in bipectinate arrangement. The paired palpi are triangular and extend only slightly beyond the ventral collar lobe. Eyes consist of a conspicuous pair of dark spots at the sides of the peristomial region and another similar pair at the sides of the pygidial lobe.

Thoracic notosetae are of two kinds; the upper are longer than the abruptly shorter lower ones; all have a terminal mucro that is longer than that shown by Wesenberg-Lund (1941, fig. 4).

The thoracic collar is obscure except for a large midventral lobe that extends across the ventrum; it is shown by Berkeley (1930, fig. 1*g*) and Wesenberg-Lund (1941, fig. 2). The body is pale yellow and has a dusky, semicircular crescent of dark pigment, open in back, across the ventrum of the thorax. The anal aperture is dorsal, located in the pygidial lobe in front of the eyespots. Tubes are cylindrical, have a translucent, chitinized base, and are loosely covered with small sand grains attached on edge or broadside.

Fabricia dubia Wesenberg-Lund was first described from the harbor of Copenhagen, Denmark, among barnacle growths. In my opinion, *F. sabella* Berkeley (1930, fig. 1*g* only), from stones at Newcastle Island, western Canada, is identical. *F. atlantica* (Treadwell) (1932) from New Brunswick, eastern Canada, is very similar except for the radiolar stalks, which are said to number only two pairs; in other respects it appears to be identical.

DISTRIBUTION: Eastern Denmark; Oregon and western Canada.

Other species of *Fabricia* from the Pacific are as follows:

1. **F. pacifica** Berkeley and Berkeley (1950: 66–67), from western Canada, taken at low tide, was earlier described as *F. sabella* Berkeley (1930: 73, 3 figs.). The thoracic collar is high and well defined; it is deeply incised on the dorsal side; peristomial and pygidial eyespots are present; abdominal uncini are long handled and have six or seven teeth, presumably in a single pectinate row.

2. **F. ventrilinguata** Johansson (1922: 9, pl. 4, figs. 1–3) is a marine species from Japan. It has only four, instead of eight, thoracic setigerous segments; the abdominal count is not known. Presumably, eyes are absent. There are three pairs of radioles that lack a weblike membrane. Abdominal uncini are handled and have teeth in pectinate series. The generic status may be doubtful because of its low segmental count.

3. **F. sabella** (Ehrenberg), 1836, originally from western Europe, is recorded by Annenkova (1938: 214) from the north Japan Sea, among corallines, without description.

4. *?F. siaukhu* (Annenkova), new combination, was originally described as *Manayunkia siaukhu* Annenkova (1938: 214, 230) from north Japan, among algae. This has tentacular radioles with pinnately arranged filaments and is thus not a species of *Manayunkia* Leidy. A thoracic collar is present; it has festooned margins and is deeply notched dorsally. The tentacular crown has three pairs of radioles; each radiole has a long slender tip and the many fine filaments end at about the same level. There are eight thoracic and three abdominal setigerous segments; the peristomium is a smooth ring. Eyes include two in the peristomium and one in the pygidium. These characters agree with those of *Fabricia*. The generic status is questionable because abdominal uncini remain unknown.

In addition, the following species belong to the genus *Fabricia* Blainville:

1. *F. capensis* (Monro), new combination, was originally described as *Oridia capensis* Monro (1937: 366–370, figs. 1–8), from South Africa. There are eight thoracic and three abdominal setigerous segments. The body is about 10 mm. long and 0.3 mm. wide, and the tubes measure 50 to 60 mm. long. The tentacular crown has three pairs of radioles, each with seven or eight filaments in (presumably) a single row. The peristomial collar is entire except for a pair of digitate lobes at the middorsum. Eyes include one pair in the peristomial ring and one pair in the pygidium. Thoracic notosetae are slender,

the neurosetae are long-handled uncini. Abdominal unicini are handled, with teeth in a pectinate row.

2. *F. atlantica* (Treadwell), new combination, was originally described as *Haplobranchus atlanticus* Treadwell (1932: 279–280, figs. 1–8) from St. Andrews, New Brunswick, in intertidal mud tubes. There are eight thoracic and three abdominal setigerous segments. The body measures about 4 mm. long. The thoracic collar is prominent on the ventral side and oblique at the sides; the dorsal end is short. The tentacular crown is incompletely known, except that it has pinnately divided radioles, each with a double row of seven or eight filaments. There are paired eyes in the peristomium and in the pygidium. Thoracic uncini are long handled; abdominal uncini are moderately long handled and have teeth in pectinate series. The second to eighth segments have slender and subspatulate setae in notopodia.

3. **F. leidyi** Verrill (1873:619), from New England, was not described until later by Leidy (1883: 210–211, figs. 14–20), based on specimens from Massachusetts and Rhode Island, found on rocks between tide marks and under patches of *Fucus*. The tubes project from the sand and mud and are firmly fixed together. Individual specimens measure 3 to 4 mm. long; color in life is yellowish brown. The thorax consists of eight and the abdomen of three setigerous segments. There are paired eyespots in the thorax and in the pygidium. The tentacular crown consists of three pairs of pinnately branched radioles with the filaments in a double row. The thorax has slender and spatulate notosetae and long-handled uncini. The abdomen has long-handled uncini above and slender setae below. A collar is not known to be present. In this respect, the species compares with the genotype, *F. sabella* (Ehrenberg). Except for the presence of spatulate thoracic setae, reportedly absent in *F. sabella*, the two are not clearly separable. Wesenberg-Lund (1941: 36) suspects the presence of spatulate setae even in the genotype and thinks they may have been overlooked.

4. **?F. alata** Ehlers (1897:135–137, figs. 206–210), from Patagonia and South Georgia in littoral zones, is questionably a species in this genus. An emended account, based on Antarctic collections, is in preparation.

Genus MANAYUNKIA Leidy, 1858

Leidy (1883: 204–211, pl. 9, figs. 1–24) gives an emended account.

The type species is *M. speciosa* Leidy, 1858.

Manayunkia includes *Haplobranchus* Bourne, 1883, *Dybowscella* Nusbaum, 1901, *Garjaiewella* Dybowski, 1929, *Fabriciella* Zenkewitsch, 1935, and *Fabriciola* Friedrich, 1940.

The tentacular crown has bases that are semicircular; radioles are simple, unbranched filaments that range in number from 16 to 36 down to only 4 pairs; they rise from a common base and are not pinnatedly arranged, thus differing sharply from *Fabricia* (above). There is no weblike or palmate membrane at the base of the crown. The peristomium lacks or has a collar that is entire or has a dorsal notch. Eyes are absent, or present as a pair in the peristomium or also pygidium. The body includes eight thoracic and three abdominal setigerous segments. The peristomium lacks setae. The setal formula agrees with that of *Fabricia* (see above).

Fabriciella Zenkewitsch (1935: 199) was proposed to include two species, *Manayunkia pacifica* Annenkova and *Fabricia* (*Manayunkia*) *spongicola* Southern, both of which are here retained in *Manayunkia* Leidy. *Fabriciella* was distinguished from *Manayunkia* Leidy mainly for having pygidial eyespots and for specific differences in the tentacular crown, both of which characteristics are given only specific distinction in the present account. For the same reason, *Fabriciola* Friedrich (1940: 362) is here regarded congeneric.

Only one species is known from the Pacific.

1. **Manayunkia pacifica** Annenkova (1934: 329–330, fig. 10) comes from the

Bering Sea in littoral zones. The body is minute, only 1.5 to 3 mm. long, and is cylindrical in shape. There are eight thoracic and three abdominal setigerous segments. The tentacular radioles number 15 to 18 on a side, are slender, unbranched, and arranged in a tuft. There is no palmate membrane, and all radioles are about equally long. The palpi are long. The thoracic collar is a simple undivided flange incised only on the dorsal side. There are paired eyes in the peristomium and in the pygidium. The setae and uncini are those characteristic of the genus. The tube is of silt and fine sand.

In addition, the following species appear to be congeneric:

1. *M. aestuarina* (Bourne), 1893, from western Europe in fresh water. (See Fauvel 1927: 326–327, fig. 113.)
2. *M. baicalensis* (Nusbaum), 1901, from Lake Baikal, in fresh water. (See Zenkewitsch, 1925: 34–35, figs. A to X.)
3. *M. caspica* Annenkova (1928: 19–20, pl. 3, figs. 1–4), from the Caspian Sea in 44–64 meters.
4. *M. polaris* Zenkewitsch (1935: 195–203, figs. 1–6), from northwest Russia at midtide level. This appears to be near *M. aestuarina* (Bourne).
5. *M. speciosa* Leidy, 1858 (see Leidy, 1883: 204–211, pl. 9, figs. 1–24), from northeast United States in fresh and brackish water, and recorded also from the western end of Lake Superior by Meehearn (1929: 479–480). *M. eriensis* Krecker (1939: 153) from Lake Erie, Ohio, in fresh water, may be the same.
6. *M. spongicola* was originally named *Fabricia* (*Manayunkia*) *spongicola* Southern (1921: 653–655, pl. 31, fig. 29) from Lake Chilka, India, in fresh water.
7. *M. baltica* (Friedrich) (1940: 363–364, figs. 1–2) from the Baltic Sea.
8. *M. bochmanni* (Friedrich) (1940: 364–365, figs. 3–4) from the Baltic Sea.

Other species that were originally described as *Manayunkia*, or under one of its synonyms, are the following:

1. *Haplobranchus balticus* Karling (1933: 242–245, figs. *a–e*), from the Baltic Sea, has unbranched radiolar filaments as in *Manayunkia* Leidy. However, there are 11 thoracic and 3 abdominal setigerous segments. The first segment has both setae and uncini. These characters do not agree with any named genus.
2. *Manayunkia africana* Monro, 1939, is here referred to *Monroika* (see below).
3. *Manayunkia siaukhu* Annenkova, 1938, is questionably referred to *Fabricia* (see above).
4. *Haplobranchus atlanticus* Treadwell, 1932, is referred to *Fabricia* (see above).

Genus *Monroika* new name

The small body, a few millimeters long, consists of a simple peristomium, eight thoracic and two abdominal setigerous segments. The tentacular crown has simple, undivided radioles in a tuft, as in *Manayunkia*, but there is a high weblike palmate membrane that unites the bases of the radioles. The thoracic collar is distinct and entire with a middorsal incision. Eyespots are lacking from the peristomium and pygidium. The first segment lacks setae. The first setigerous segment has notosetae only. The second to fifth have slender and spatulate notosetae and long-handled uncini. Segments 6 to 8 are similar but lack spatulate notosetae. Abdominal segments have handled uncini with teeth in pectinate rows; neurosetae are slender. *Monroika* differs from *Manayunkia* especially in having a weblike membrane in the crown. A single species is known.

Monroika africana (Monro) is the type species.

Monroika africana (Monro) new combination

Manayunkia africana Monro (1939: 220–223, figs. 1–5).

Length of the body is about 2 mm. The weblike tentacular membrane extends distally for about a third of the radiolar length. Radioles number about 12. The species is known only from the Congo River, about

150 km. from the sea and beyond tidal effects; it occupies sandy tubes on mollusk shells and in incrustations on stones.

Genus ORIDIA Rioja, 1917

This genus differs from *Fabricia* Blainville essentially in having abdominal uncini that lack a handle. There are 8 thoracic and 3 to 12 abdominal setigerous segments. Tentacular radioles number two to five pairs and have filaments in pinnate arrangement. A thoracic collar is present or absent. Peristomial and pygidial eyespots are present. Thoracic uncini resemble those of *Fabricia*. Four species are recorded from the Pacific (see above). One is here newly referred to *Oridia*.

Oridia armandi (Claparède), 1864, is the type species.

Oridia minuta (Berkeley and Berkeley) new combination

Fabricia minuta Berkeley and Berkeley (1932: 315–316, figs. A–E).

Total length is about 11 mm. and width is about 0.1 mm. The body consists of eight thoracic and three to five abdominal setigerous segments. The tentacular crown consists of two pairs of radioles with pinnately arranged filaments. A thoracic collar is lacking. Peristomial and pygidial eyespots are present. Thoracic notosetae are slender and subspatulate. Thoracic uncini are sharply curved; abdominal uncini lack a stem.

This species is known only from the west coast of Vancouver Island, Canada, from among algae.

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The Ecology of the Mosquito Larvae of New Guinea

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INTRODUCTION

FROM SEPTEMBER 1943 to January 1945 I was in New Guinea as Officer in Charge, U. S. Navy Malaria Control Team 25, and was stationed at Milne Bay, Morobe, Finschhafen, and Saidor. The entire period was spent in almost daily field collecting of larval mosquitoes. During the same period Dr. George H. Penn was stationed at Milne Bay, Amsterdam Island, and Woendi Island as Officer in Charge, U. S. Navy Malaria Control Team 28. Before arriving in New Guinea we agreed to combine all collections and to record all habitat data on standard collection cards.

This study is based on an analysis of the habitats utilized by 47 species of mosquitoes present in a total of 1,508 collections. The habitat records presented here are not the results of opinions on habitat relationships; they are numerical analyses of all collection data.

Comprehensive studies of the ecology of the mosquito larvae of New Guinea are completely lacking. There are numerous scattered notes on habitat, especially for the more recently described species, and there are more detailed ecological studies of certain of the medically important species. But there is no broad ecological survey summarizing the habitat relationships of all common species of this area.

Some of the more important taxonomic works in which ecological notes may be found are those of Taylor (1914–1943), Hill (1925), Bonne-Wepster and Brug (1932, 1937, 1939), Lee (1944*a*, 1946), Lee and Woodhill (1944), King and Hoogstraal (1946–1947), and Marks (1947). Recently more detailed habitat studies of individual species of medical importance have been recorded by Horsfall and Porter (1947), Forbes and Horsfall (1947), and Penn (1947*a*).

Acknowledgments. Many persons have assisted in this study. I wish to thank Professor Robert Matheson, Cornell University, for his friendly encouragement and counsel. Dr. George H. Penn, Tulane University, assisted in developing the collecting technique; and made many of the collections. My appreciation is extended to the men of Malaria Control Teams 25 and 28 (W. W. Bonds, H. W. Dorman, A. S. Griswold, J. E. Surgenor, W. T. Whitfield, P. B. Tompkins, O. L. Andrews, A. C. Bodenman, W. L. Schmid, R. E. Geiger, J. P. Gallagher, and M. A. Greenblatt) by whose efforts many collections were made, often under trying field conditions. Professor F. A. Perkins, University of Queensland, extended every courtesy, including the full facilities of his Department, and Miss Elizabeth Marks of the same institution identified many specimens and supplied important literature aids. Dr. Alan Stone, U. S. National Museum, clarified many of the taxonomic problems. Dr. W. M. Rogoff and Dr. A. G. Humes supplied species lists to add to the distribution data.

LOCALITIES STUDIED

All collections were made within, or just adjacent to, military bases which in every case were situated along the North Coast. In general, these bases were built on strips of land lying between the ocean and the mountains, and varying in width from about a quarter of a mile to 5 miles. However, Woendi and Amsterdam were small coral islands.

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The most conspicuous feature of all areas was the ubiquitous coconut plantation. In most instances, puddles and artificial containers were common, whereas ponds, lakes, and marshes were nearly always absent. New habitats developed rapidly. The most outstanding of these were puddles and artificial containers. Moreover, each area was under intensive military control and, in several, thorough initial surveys were delayed because of enemy interference.

The above factors undoubtedly influenced the data. However, since each area was bordered by an accessible fringe roughly representative of natural conditions, and since collections were from both base periphery and from the more artificial base site, it is believed that significant data on the *habitat potentials* of the various species have been obtained.

The collecting areas and dates are:

Milne Bay, Papua (10° 20′ S/150° 30′ E).
  Gamadodo: September 1943 through March 1944; September through November 1944.
  Wagga Wagga: October through November 1944.
  Hilimoi: August through November 1944.
  Kana Kopa: October 1943 through January 1944; September through November 1944.
Morobe, Northeast New Guinea (7° 45′ S/147° 35′ E): November 1943.
Finschhafen, Northeast New Guinea (6° 35′ S/147° 50′ E): January through June 1944.
Saidor, Northeast New Guinea (5° 40′ S/146° 30′ E): February through June 1944.
Woendi, Padaido Islands, Dutch New Guinea (1° 15′ S/136° 20′ E): July through October 1944.
Amsterdam Island, Dutch New Guinea (0° 20′ S/132° 10′ E): August through October 1944.

METEOROLOGICAL DATA

The only data available were those of the temporary Navy Station at Milne Bay and the Australian Station at Samarai. Rainfall and temperature records for 1943 and 1944 were obtained from the Navy, and the long-time averages from Samarai. Since the majority of collections were from Milne Bay, data from these sources are indicative of conditions under which most of the collections were obtained.

Figure 1 compares the 29-year average monthly rainfall with that for the collecting period. It also compares the 9-year average monthly maximum, mean, and minimum temperatures with those for the collecting period.

The 29-year average rainfall shows no great monthly variation. Rainfall during the collecting period paralleled the long-time average, except during April and June 1944, when brief torrential rains increased the amount to far above the average. No collections were obtained from Milne Bay during these months. These data demonstrate an absence of definite wet and dry seasons. This is in marked contrast to the much-discussed wet and dry seasons which have played such an important role in mosquito bionomics in other tropical areas, notably the Solomon Islands and the New Hebrides. Similarly, temperature data show but slight seasonal variation.

No seasonal fluctuation in numbers of species or numbers of individuals of mosquito larvae was observed. It is concluded that neither rainfall nor temperature was a factor limiting the mosquito population during any season of the year.

METHODS

Distribution

Data were obtained from: (1) literature records; (2) collections from the detail-study areas; (3) unpublished records of A. H. Humes, W. M. Rogoff, and T. K. Ruebush, who were in New Guinea during periods corresponding to these collections.

All records available in the literature on New Guinea are listed for each of the 47

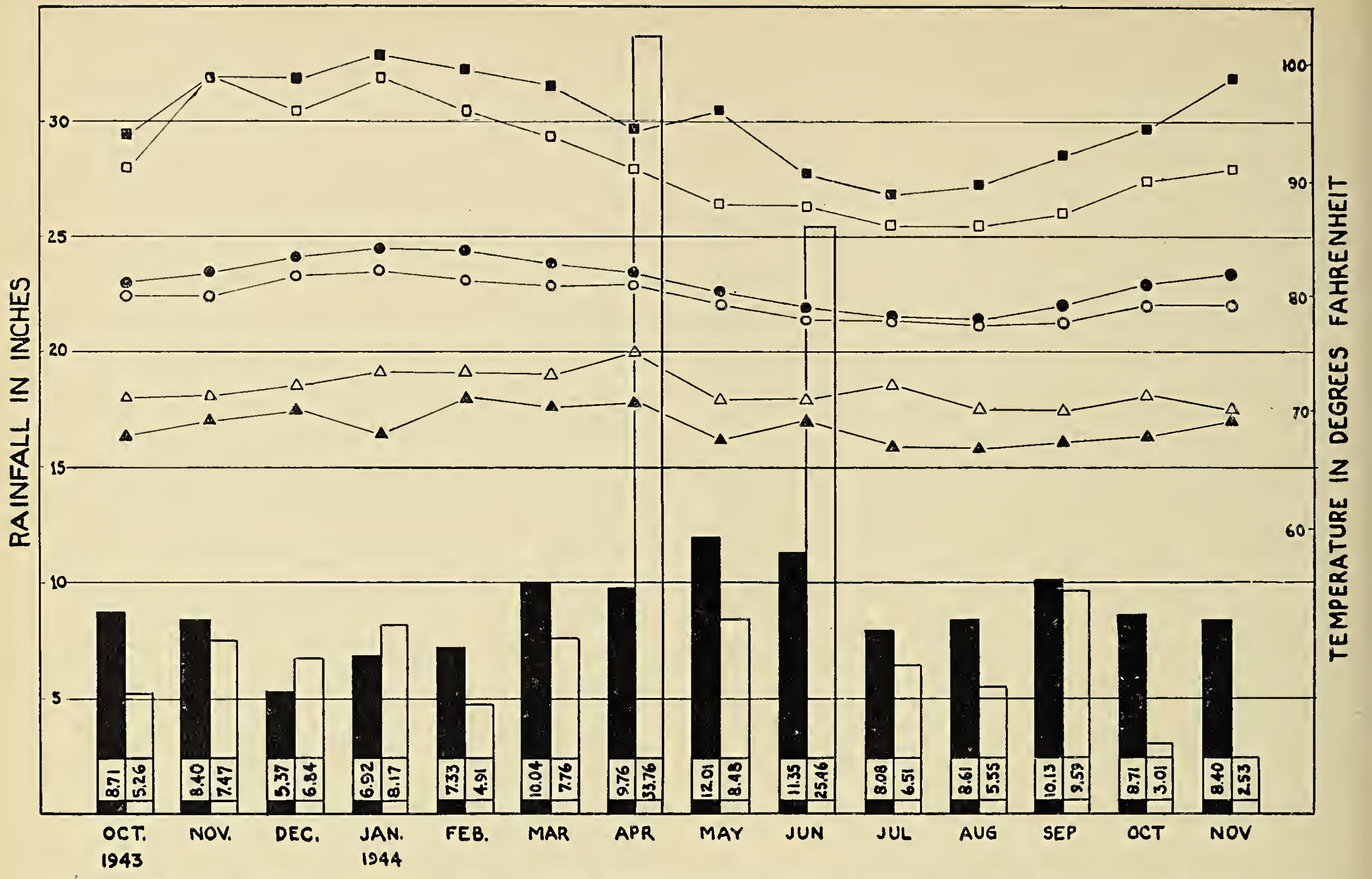

FIG. 1. Monthly temperature and rainfall during collecting period at Milne Bay (open symbols and blocks) compared with the long-time average for the Samarai weather station (solid symbols and blocks). Long-time average figures were obtained through courtesy of Directorate, Meteorological Services, RAAF, Melbourne.

species[2] collected in the areas of study. When the same locality is repeated by several authors, each reference is included. All type localities in New Guinea are given, but additional references to this locality are not repeated. Latitude and longitude for nearly every locality may be found in the U. S. Army Map Service *Gazetteer to Maps of New Guinea* (1943).

A great variety of spellings of the various place names was encountered. Moreover, many of the German names employed in Northeast New Guinea were changed after the area became an Australian mandate. To avoid confusion, all spellings used in this report are those given in the Army's *Gazetteer.*

Collecting Technique

Each collection was a sample from a particular microhabitat at a particular time. Each microhabitat usually presented at least one distinguishing characteristic, even when several of them were located in temporary water in close proximity. A single macrohabitat often included a large number of microhabitats in a very limited horizontal range. For example, in certain cases the superficial picture may have been of a definite marsh, yet separate collections could be made from puddles, artificial containers, coconut shells, etc., through a great range of microhabitats. As a result of sanitary control operations, repeat collections from the same microhabitat were seldom possible.

All ecological data were recorded in the field, using for each collection a 3×5 index card whereon space was provided in the center for recording the locality, date, time, and collector's initials. Ecological terms were listed around the margins so the collector simply checked the appropriate blocks. This method reduced the possibility of omitting important data from field notes compiled at random. A similar card punch system is discussed by Boyd (1930).

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[2] In the thesis on which this paper is based (deposited in the library of Cornell University) I have listed all distribution records of the 179 species ever recorded from New Guinea as well as my own distribution records for the 47 species discussed in this paper. In addition, all literature on the ecology of the larvae of each of the 179 species was summarized and compared with my own numerical data. However, for the sake of brevity, this paper deals primarily with distribution and ecological data for the 47 species I personally encountered.

Identifications

For most collections, a representative series of individuals was reared in isolation. Identifications in nearly every case were based on reared material. The majority of these reared adults were checked by Dr. Alan Stone of the U. S. National Museum, and others were checked by Miss Elizabeth Marks of the University of Queensland. Most of the specimens have been deposited in the U. S. National Museum, and representative series of associated larvae, pupae, and adults have been placed in the collections of Cornell University and the University of Queensland, Brisbane, Australia.

ANALYSIS OF DATA

Habitats

After all recorded data on the ecology of the larvae were assembled, it became obvious that the literature was markedly deficient in quantitative data. Scarcely a reference presents numerical data which show the actual degree of utilization of a habitat. Some authors use such terms as "sometimes," "rarely," "frequently," but most merely list all habitats without qualification, so that it is impossible to distinguish the usual from the unusual. Undoubtedly, many authors unduly stress rare habitats. It seems that single collections from such breeding places are so repeated in the literature that gradually the focus is concentrated on the rare to the point of neglecting the really important—the usual.

Therefore, I believe that only a numerical presentation of data can furnish both a brief and an accurate basis for determining habitat potentials, and only the use of numbers will permit a comparison of the results of different studies.

Larval habitats have been variously recorded by nearly every author who has attempted to summarize an extensive number of collections. The majority simply give the range of habitats applicable to the particular area, listing every specific habitat, such as "K ration box floating in a river." Such details are meaningless when data are compared. Moreover, even though some authors attempt to classify habitats, their descriptive terms are unique. Thus, comparison of data is almost impossible. Obviously there is need for a classification of habitats using very broad terms that are universally applicable.

Shannon (1931) proposed a very general classification dividing all habitats into two major categories: (1) depressions in the ground, and (2) water in containers above ground. He subdivided each of these into natural and artificial water. Bonne-Wepster and Brug (1932) found the following adequate for their investigation of *Stegomyia* in the Dutch East Indies: (1) earth-bound habitats, (2) vegetable breeding places, (3) man-made containers. Bates (1949) divided larval habitats into four major groups: (1) permanent or semipermanent standing water, (2) running water, (3) transient ground pools, (4) container habitats. Arnett (1950) summarized the habitats recognized in Panama as follows: (1) surface water, (2) aerial habitats, (3) artificial containers.

I believe that general use of such major categories by all workers, supported by numerical data, would quickly give an adequate picture of the habitat potentials of the various species. Such a picture could then be utilized as the basis of sound control procedures.

My organization of larval habitats corresponds to that of Bonne-Wepster and Brug and of Shannon. They were grouped into three major divisions: (1) fresh surface water, both natural and artificial, (2) fresh water in containers, both natural and artificial, (3) brackish or salt water. These were further divided into a rather large number of more specific microhabitats, which are listed in Table 2.

The term "habitat index" is used as a convenient way of referring to the ratio between the number of collections of a species in a particular habitat and the total number of collections of that species.

Habitat Factors

An extensive literature has accumulated in an attempt to determine the effect of chemical and physical factors on the breeding habits of various species. Many factors have been investigated, but specific conclusions concerning the role of any one factor as an absolute indicator of potential breeding are almost entirely wanting.

A comprehensive quantitative study of the physio-chemical factors such as light intensity, dissolved oxygen, etc., was impossible under our field conditions. Our aim was to describe the general character of the habitat by careful observations using quantitative determinations when possible. Therefore only major factors such as exposure, superficial character of the water, vegetation, *p*H, were considered. In this report the habitat factor is given as the percentage of our collections in which that factor was recorded.

It should be noted that stagnant water was always static, with varying amounts of organic debris in the early stages of decomposition. In polluted water, decomposition was always well advanced and produced a foul smell. *p*H was determined in the field for many but not for all collections, using Squibb's nitrazene paper (range 4.5–8.0). Salinity was measured with a hydrometer in all cases of suspected brackish water and was considered experimentally for *An. punctulatus* and for *An. farauti*.

Species Association

The most common method of presenting numerical data indicating the degree of association is in the form of a table showing the actual number of times any two species were found together in individual collections. However, Hacker (1921) proposed the "Association Unit" and Dice (1945) the "Association Index" as measures of the degree of association between species. A combination of the methods of Hacker and Dice was used in determining my association indices.

Collections of any one species were either pure or in various combinations with one or more additional species of mosquito larvae. The value (P) of pure collections for any one species (A) is the ratio between the number of times the species was collected alone and the total collections of species A. Then a measure of the value of mixed collections (M) can be taken as 100-P. Each cohabitant is assigned a relative portion of this total as follows: hM/t, where h equals the number of times species A was found with any other species and t equals the number of times species A was found with all cohabitants. In this paper, species having an association of less than 4 per cent have been grouped and given as "others."

BIRONELLA

Because of the confusing status of various species in the genus *Bironella*, it was impossible accurately to determine species of this genus during the collecting period. Laboratory rearing was so difficult that only five adults were available for checking: two specimens from Milne Bay were identified by Dr. Stone as *B. travestitus* and three from the same locality as *B. soesiloi* sensu Swellengrebel and Rodenwaldt. Because of the rather limited literature on the biology of *Bironella* it is considered worth while to present these data even though more than one species is represented.

DISTRIBUTION: *Bironella* species were present in collections from Milne Bay, Morobe, Finschhafen, and Saidor. Collections were nowhere numerous and the number of individuals in each collection was always rather limited. It seems that *Bironella* species would have been represented more abundantly if extensive collecting had been possible from the headwaters or at least from the higher reaches of the mountain streams.

HABITAT:

Total collections, 34

Habitat	Number of collections	Habitat index
Creeks: Pot holes	19	56
Creeks: Running	14	41
Rock holes	1	3

*p*H, 11 readings

Range	4.0–6.5
Mode	5.0
Average	5.1

Factor	Percentage occurrence
Shaded	76
Exposed	24
Temporary	3
Semi-permanent	56
Permanent	41
Clear	100
Vegetation	
Absent	56
Present	44
Sparse	30
Moderate	47
Abundant	23
Algae	17
Emergent	17
Overhanging	50
Submerged	11
Floating	5

The genus *Bironella* occurred mostly (68 per cent) in pure collections. Percentages of associates were: *U. argyrotarsis*, 11; *C. fraudatrix*, 9; *C. pullus*, 4; others, 8.

Bironella (Bironella) soesiloi sensu Swellengrebel and Rodenwaldt

"*B. papuae* No. 22147 (B. soesiloi Strickland)" Soesilo and van Slooten, 1931, Geneesk. Tijdschr. Nederland. Indië 71: 126.

Anopheles papuae soesiloi Strickland (Bei Soesilo and van Slooten, 1931) Swellengrebel and Rodenwaldt (1932: 62).

DISTRIBUTION: Dutch New Guinea: Boemi-Bezirk, Hollandia (Swellengrebel and Rodenwaldt, 1932). Lee and Woodhill record it as questionable from Boemi and Hollandia. Papua: Milne Bay (Lee and Woodhill, 1944; Author).

HABITAT: Lee and Woodhill (1944) record it from a swampy creek. Both of my collections were from pot holes in creeks, in fresh, temporary, clear, shaded water at a *p*H of 5. It was found once in a pure collection and once with *U. argyrotarsis*, *C. papuensis*, and *B. travestitus*.

Bironella (Brugella) travestitus (Brug)

Anopheles (*Bironella*) *travestitus* Brug, 1928, Geneesk. Tijdschr. Nederland. Indië 68: 921.

DISTRIBUTION: Dutch New Guinea: Tahahmerah (Swellengrebel and Rodenwaldt, 1932). Papua: Cape Endaiadere (Lee and Woodhill, 1944); Milne Bay (Lee and Woodhill, 1944; Author).

HABITAT: Lee and Woodhill record it in partially shaded swamps and in pools in a sago swamp. My single collection was from a temporary, shaded pot hole in a creek, with a sparse amount of debris, at a *p*H of 5, and in association with *U. argyrotarsis*, *C. fragilis*, and *B. soesiloi* sensu Swellengrebel and Rodenwaldt.

Anopheles (Anopheles) bancrofti pseudobarbirostris Ludlow

Anopheles pseudobarbirostris Ludlow, 1902, N. Y. Ent. Soc. Jour. 10: 129.

DISTRIBUTION: Northeast New Guinea: Sepik River, Madang (Lee and Woodhill, 1944); Saidor (Author). Papua: Cape Endaidere, Oro Bay, Terapo, Lalapipi, Dobodura (Lee and Woodhill, 1944); Milne Bay (Lee and Woodhill, 1944).

HABITAT: Lee and Woodhill state that it is found only in the jungle, usually in clear pools with abundant aquatic vegetation, in dense shade, or in places which receive direct sunlight only during the middle of the day.

In our survey, *pseudobarbirostris* was present in three collections from ponds with vegetation. Its scarcity may be due to the fact that its chief habitat seems to be rather large, permanent, well-vegetated bodies of clear, shaded water which were almost entirely absent in the study areas. It was collected with *An. punctulatus*, *An. farauti*, *U. argyrotarsis*, and *C. fraudatrix*.

Anopheles (Myzomyia) farauti Laveran

Anopheles farauti Laveran, 1902, Soc. de Biol. [Paris] Compt. Rend. 54: 908.

Anopheles punctulatus molluccensis Sw. and Sw. de Graaf. Lee and Woodhill (1944: 140).

Anopheles punctulatus farauti Laveran. Mackerras and Aberdeen (1946: 770); Mackerras (1947: 1–8).

In 1945 Owen described *An. koliensis* from the Solomons. This form is intermediate between *An. punctulatus* and *farauti*. Certain earlier workers have long recognized "intermediates" which are clearly *koliensis;* others make no distinction. Obviously, in the latter cases the material cannot be safely referred to any of the three species (or subspecies) of the complex. I have limited the literature in the following discussions to those who, apparently, were clearly aware of *koliensis* or at least of intermediate forms. I believe that most of my material is *farauti* but, since all of the collections were made without knowledge of *koliensis* and since only a relatively few individuals were available for subsequent careful checking, certainty is impossible.

DISTRIBUTION: Dutch New Guinea: Bataviabivak, Motorbivak, Kokas, Kaimana, Fakfak, Prauwenbivak, Tanahmerah, Sorong, Meervlakte, Salawati, Biak Island, Japen Island, Aru Island (Lee and Woodhill, 1944); Hollandia (Lee and Woodhill, 1944; Rozeboom and Knight, 1946); Merauke (Lee and Woodhill, 1944; Mackerras, 1947); Padaido Islands, Amsterdam Island (Author). Northeast New Guinea: Lae, Salamaua (Lee and Woodhill, 1944); Ramu Valley (Mackerras, 1947); Wewak (Mackerras and Aberdeen, 1946; Mackerras, 1947); Finschhafen, Saidor (Author). Papua: Samarai, Port Moresby, Koitaki, Oro Bay, Dobodura (Lee and Woodhill, 1944); Lalapipi (Lee and Woodhill, 1944; Mackerras, 1947); Bulldog, and near mouth of Lakekamu River (Horsfall and Porter, 1947); Milne Bay (Lee and Woodhill, 1944; Mackerras, 1947; Author).

HABITAT:

Total collections, 170

Habitat	*Number of collections*	*Habitat index*
Puddles	89	52
Creeks: Running	26	15
Creeks: Pot holes	23	14
Swamps	9	5
Borrow pits	8	5
Ditches	5	3
Ponds	3	2
Marshes	2	1
Coral pools	2	1
Artificial containers	2	1
Rock holes	1	0

*p*H, 67 readings

Range	4.0–8.0
Mode	5.0
Average	5.7

Factor	*Percentage occurrence*
Shaded	25
Exposed	75
Temporary	55
Semi-permanent	21
Permanent	24
Clear	66
Muddy	17
Stagnant	15
Polluted	2
Vegetation	
Absent	39
Present	61
Sparse	30
Moderate	43
Abundant	27
Algae	42
Emergent	25
Overhanging	16
Submerged	10
Floating	7

In the New Hebrides and Solomon Islands, Belkin *et al.* (1945), Perry (1946), and Daggy (1945) found that the breeding places consisted primarily of relatively large collections of surface water, but that after heavy rains a great variety of small temporary water collections was used. In New Guinea, Lee and Woodhill (1944) considered sago swamps, backwaters of creeks, and grassy pools and puddles as common habitats. Horsfall and Porter (1947) also give natural pools and grassy margins of streams as most frequently used sites. Nearly all of these recorded habitats are represented in my collections. However, *farauti* was collected almost entirely (99 per cent) in surface water; the only other habitat represented was artificial containers. The range of surface habitats was rather wide but these data clearly show the great relative importance of puddles.

All workers in the New Hebrides-Solomons area have emphasized the contrast in utilization of wet- and dry-season breeding sites. No such contrast was apparent from my observations nor has such been reported by other workers in New Guinea.

Seventy-five per cent of my collections were made in exposed situations. All authors state that *farauti* occurs both in sun and shade; however, Belkin *et al.* (1945), Daggy (1945), Perry (1946), and Horsfall and Porter (1947) give a preference for sunlight, whereas Lee and Woodhill (1944) give a preference for semi-shade.

Vegetation was present in 61 per cent of my collections. Lee and Woodhill (1944), Belkin *et al.* (1945), Perry (1946), and Horsfall and Porter (1947) consider the presence of vegetation or floatage of prime importance in the ecology of *farauti*.

Only 17 per cent of my *farauti* collections were taken from muddy water, whereas 32 per cent of the *punctulatus* collections were from muddy water. This difference was emphasized by Lee and Woodhill (1944), who stated that *farauti* is rarely recorded in man-made pools with a heavy suspension of clay but that such pools serve as the typical breeding place of *punctulatus*. Horsfall and Porter (1947), on the basis of quantitative data, concluded that *farauti* is dominant in sandy or mucky soil whereas *punctulatus* is dominant in heavy clay.

Nothing on *p*H relationships has been reported. My 67 readings from nearly all habitats show a very wide range (4.0 to 8.0). However, both the mode and the average were approximately 5.5.

Lee and Woodhill (1944) record *farauti* at a salinity of 1.4 per cent at Goodenough Island. Perry (1946), in the New Hebrides-Solomons area, found it common in water containing less than 70 per cent sea water, and stated that its upper maximum level was 75 per cent sea water. From a total of 170 collections in strictly coastal localities, only four were taken in brackish water on Amsterdam Island. Two were from puddles at salinities of 10 per cent sea water, one was from a coral pool at a salinity of 20 per cent, and one from a similar pool at 70 per cent sea water.

Daggy (1945) reared *farauti* from egg to adult at a maximum of 65 per cent sea water and found that "late larval development" was possible in salinities greater than that of sea water. My laboratory investigations showed that fourth instar larvae withstood all concentrations up to 100 per cent sea water for 24 hours, but that the survival was greatly reduced at salinities greater than 30 per cent.

SALINITY

Percentage sea water	*Number of larvae used (4th instar)*	*Percentage alive after 24 hours*
0	21	100
10	7	100
20	11	60
30	21	76
40	22	23
50	23	9
60	15	7
70	20	5
80	18	5
90	15	0
100	36	3

Larval associates have been recorded by Buxton and Hopkins (1927), Belkin *et al.* (1945), and Perry (1946), but no one has recorded the degree of association. *Farauti* occurred mostly (77 per cent) in mixed collections. Percentages of associates were: *C. pullus*, 21; *An. punctulatus*, 16; *C. halifaxi*, 11; *C. squamosus*, 8; *C. annulirostris*, 6; *C. fraudatrix*, 5; *U. argyrotarsis*, 4; others, 6.

Anopheles (Myzomyia) longirostris Brug

Anopheles (*Neomyzomyia*) *longirostris* Brug, 1928, Geneesk. Tijdschr. Nederland. Indië 68: 278. Type locality: Near Upper Digoel River, Dutch New Guinea.

DISTRIBUTION: Dutch New Guinea: Pionierbivak (Lee and Woodhill, 1944); Fakfak, Tanahmerah, hinterland of Geelvink Bay (Swellengrebel and Rodenwaldt, 1932). Northeast New Guinea: Lae (Lee and Woodhill, 1944). Papua: Sinemi, Port Moresby (Lee and Woodhill, 1944); Bulldog (Lee and Woodhill, 1944; Mackerras, 1947); Milne Bay (Lee and Woodhill, 1944; Mackerras, 1947; Author).

HABITAT: Swellengrebel and Rodenwaldt (1932) and Lee and Woodhill (1944) recorded *longirostris* most often from shaded swamps and pools in the jungle or near its fringes. My single collection was taken from a temporary, exposed puddle, in fresh clear water having a sparse amount of algae, in association with *An. farauti*, *An. punctulatus*, and *C. pullus*.

Anopheles (Myzomyia) punctulatus Dönitz

Anopheles punctulatus Dönitz, 1901, Insekten Börse 18: 36. Type locality: Bogadjim, Northeast New Guinea.

Anopheles punctulatus punctulatus Dönitz. Lee and Woodhill (1944: 134); King and Hoogstraal (1946*b*: 153–156); Mackerras (1947: 1–8); Mackerras and Aberdeen (1946: 770).

DISTRIBUTION: Dutch New Guinea: Pionierbivak, Tanahmerah (Lee and Woodhill, 1944; Mackerras, 1947); Aru Islands, Meervlakte, Bataviabivak, Motorbivak, Fakfak, Japen Island, Idore (Lee and Woodhill, 1944); Biak (Lee and Woodhill, 1944; Horsfall and Porter, 1947); Hollandia (Lee and Woodhill, 1944; Rozeboom and Knight, 1946; King and Hoogstraal, 1946*b*); Wamal (Mackerras, 1947); Padaido Islands (Author). Northeast New Guinea: Bogadjim (Dönitz, 1901); Sepik River, Lae, Salamaua, Bulolo, Upper Watut (Lee and Woodhill, 1944); Wau (Lee and Woodhill, 1944; Horsfall and Porter, 1947); Ramu Valley, Maprik (Mackerras, 1947); Wewak (Mackerras and Aberdeen, 1946; Mackerras, 1947); Alexishafen (T. K. Ruebush); Finschhafen, Saidor (Author). Papua: Cape Endaiadere, Koitaki, Dobodura (Lee and Woodhill, 1944); Port Moresby (Lee and Woodhill, 1944; Horsfall and Porter, 1947); Bulldog (Lee and Woodhill, 1944; Mackerras, 1947; Horsfall and Porter, 1947); near mouth of Lakekamu River (Horsfall and Porter, 1947); Milne Bay (Lee and Woodhill, 1944; Mackerras, 1947; Author).

HABITAT:

Total Collections, 151

Habitat	*Number of collections*	*Habitat index*
Puddles	125	83
Ditches	8	5
Swamps	6	4
Creeks: Pot holes	5	3
Creeks: Running	3	2
Ponds	2	1
Borrow pits	1	1
Artificial containers	1	1

*p*H, 27 readings

Range	5.0–7.0
Mode	7.0
Average	6.0

Factor	*Percentage occurrence*
Shaded	16
Exposed	84
Temporary	83
Semi-permanent	10
Permanent	7
Clear	56
Muddy	32
Stagnant	11
Polluted	1
Vegetation	
Absent	55
Present	45
Sparse	37
Moderate	44
Abundant	19
Algae	49
Emergent	11
Overhanging	10
Submerged	22
Floating	8

Punctulatus is widespread throughout New Guinea but collections from the interior are still too meager to prove the interesting hypothesis of Taylor (1934) that *punctulatus* supplants *farauti* in inland localities. This hypothesis is discussed by Lee and Woodhill (1944) and Horsfall and Porter (1947).

Punctulatus was recorded almost entirely (99 per cent) from surface water; the only other habitat utilized was artificial containers. It was collected from a variety of surface habitats but my evidence is overwhelming that only puddles are important. Puddles were the important habitat of both *farauti* and *punctulatus*, but *punctulatus* showed a considerably greater affinity for this habitat (*punctulatus* in puddles, 83 per cent; *farauti* in puddles, 52 per cent). Furthermore, 32 per cent of the *punctulatus* collections were taken from muddy water, in contrast to 17 per cent for *farauti*. Lee and Woodhill (1944), Belkin *et al.* (1945), and Horsfall and Porter (1947) have all emphasized small, temporary surface-water collections as the principal habitat.

In the Solomons, Belkin *et al.* (1945) recorded a contrast in wet- and dry-season habitats. They state that, during the dry season, *punctulatus* almost disappears and is found mainly in streams, whereas, during the wet season, it is found in an endless variety of surface waters. No such contrast was apparent from my observations, nor has such been recorded by others for New Guinea.

Swellengrebel and Rodenwaldt (1932), by listing a great variety of artificial containers, have given undue stress to the utilization of this habitat. Neither Lee and Woodhill (1944) nor Belkin *et al.* (1945) recorded *punctulatus* from artificial containers, and Horsfall and Porter (1947) reported that tin cans were rare habitats.

Lee and Woodhill (1944) and Belkin *et al.* (1945) emphasized that *punctulatus* is found primarily in sunlight. My figure, 84 per cent for exposed situations, is in striking agreement.

Punctulatus was recorded approximately to the same degree both with and without vegetation, and this is in general agreement with Lee and Woodhill (1944) and Belkin *et al.* (1945). However, Horsfall and Porter (1947) state that *punctulatus* habitats are essentially those free of floatage.

Nothing relative to *p*H has been recorded. My data, from 27 readings, give a range of 5 to 7 and a mode of 7, which is significantly higher than the mode of 5 recorded for *farauti*.

Lee and Woodhill (1944) state that *punctulatus* has not been found in brackish water, and none of my 151 collections was from such habitats. However, Horsfall and Porter (1947) did record it rarely from brackish water.

The salt tolerance of *punctulatus* under laboratory conditions apparently has not been reported. My laboratory studies showed that the percentage of fourth instar larvae surviving for 24 hours was greatly reduced only at salinities greater than 50 per cent sea water. Percentage emergence of fourth instar larvae in 10 per cent sea water was identical with that in distilled water, but was significantly reduced at all higher salinities. However, fourth instar larvae emerged to a limited degree at all salinities including 100 per cent sea water. This is particularly interesting because of the absence of brackish water collections.

SALINITY

Percentage sea water	*Number of larvae used (4th instar)*	*Percentage alive after 24 hours*	*Percentage emerging*
0	108	97	33
10	60	83	33
20	58	60	2
30	82	74	8
40	97	57	6
50	87	44	4
60	52	19	11
70	65	5	2
80	64	11	10
90	67	4	2
100	121	4	3

Nothing has been recorded relative to larval associates. *Punctulatus* was found mostly

(65 per cent) in mixed collections. Percentages of associates were: *C. pullus*, 18; *An. farauti*, 15; *C. halifaxi*, 12; *C. annulirostris*, 6; *C. squamosus*, 5; others, 9.

Toxorhynchites spp.

In our series of reared individuals, only adult females are represented, so that accurate specific determinations are impossible. However, because many collections of larvae were obtained, it is considered worth while to give my distribution and habitat data for the genus even though possibly more than one species is represented.

DISTRIBUTION: The genus is represented in my records from Padaido Islands, Saidor, Finschhafen, and Milne Bay.

HABITAT:

Total collections, 59

Habitat	*Number of collections*	*Habitat index*
Artificial containers	40	68
Tree holes	9	15
Coconut shells	9	15
Rock holes	1	2

*p*H, 22 readings	
Range	4.0–8.0
Mode	5.0–5.5
Average	5.6

Factor	*Percentage occurrence*
Shaded	73
Exposed	27
Temporary	84
Permanent	16
Clear	43
Muddy	10
Stagnant	39
Polluted	8
Vegetation	
Absent	100

Newkirk (1947) found *Toxorhynchites splendens* commonly in rain barrels and once in a latrine pit at Milne Bay. My specimens were found most abundantly in artificial containers. They occurred to an approximately equal extent in pure (52 per cent) and in mixed collections. Percentages of associates were: *A. scutellaris*, 6; *T. bimaculipes*, 5; *A. albolineatus*, 5; *Arm. breinli*, 5; *C. fragilis*, 5; others, 22.

Tripteroides (Rachisoura) confusa Lee

Tripteroides (*Rachisoura*) *confusa* Lee, 1946, Linn. Soc. N. S. Wales, Proc. 70: 251. Type locality: Milne Bay, Papua.

"Known with certainty only from the type locality but probably quite widely distributed. This is very likely the species which has usually been called *T. atra*, owing to the paratype of that name seen by Edwards not being conspecific with the type." (Lee, 1946.)

Lee (1946) recorded *T. confusa* from tins and coconut shells, in association with *T. bimaculipes*. My single pure collection from Milne Bay was from a taro leaf axil in clear, temporary, shaded water.

Tripteroides (Mimeteomyia) argenteiventris (Theobald)

Polylepidomyia argenteiventris Theobald, 1905, Mus. Nat. Hungarici Ann. 3: 118. Type locality: Paimumu River, Papua.

DISTRIBUTION: Dutch New Guinea: Assike, Merauke, Tanahmerah (Bonne-Wepster, 1938); Hollandia (Lee, 1946). Northeast New Guinea: Tsili Tsili, Nadzab (Lee, 1946); Lae (Lee, 1946; Mackerras, 1946); Finschhafen (Author). Papua: Paimumu River (Theobald, 1905); Dobodura (Lee, 1946); Milne Bay (Lee, 1946; Author).

HABITAT:

Total collections, 7

Habitat	*Number of collections*	*Habitat index*
Coconut shells	4	57
Artificial containers	3	43
*p*H, one reading	4.0	

Factor	*Percentage occurrence*
Shaded	100
Temporary	100
Clear	33
Stagnant	56
Polluted	11
Vegetation	
Absent	100

Brug (1934) reported *argenteiventris* from leaf axils of *Curcuma* plants, and Lee (1946) stated that it has been found in relatively fresh water in tins, in old coconuts, and in tree holes. I did not collect it from tree holes or from leaf axils. *Argenteiventris* occurred to an approximately equal degree in pure (43 per cent) and in mixed collections. Associates were: *A. scutellaris* (19 per cent), others (38 per cent).

Tripteroides (Tripteroides) bimaculipes (Theobald)

Phoniomyia bimaculipes Theobald, 1905, Mus. Nat. Hungarici Ann. 3: 114. Type locality: Moroka, Papua, and Madang, Northeast New Guinea.

Stegomyia ornata Taylor. Taylor (1914*a*: 189); Breinl (1915: 317); Edwards (1924: 361). Synonymy in Lee (1946: 231).

DISTRIBUTION: Dutch New Guinea: Hollandia (Lee, 1946; King and Hoogstraal, 1946*c*, *f*); Nakasawa, Sapari, Mt. Dafonsero, Doromena (Lee, 1946); Assike, Merauke, Tanahmerah, Explorateurbivak (Bonne-Wepster, 1938); Amsterdam Island (Author). Northeast New Guinea: Madang (Theobald, 1905); Lakekamu Gold Field (Breinl, 1915); Lae (Lee, 1946; Mackerras, 1946); Tsili Tsili (Lee, 1946). Papua: Moroka (Theobald, 1905); Milne Bay (Taylor, 1914*a*; Edwards, 1924; Lee, 1946; Author); Lalapipi, Bulldog, Dobodura, Buna, Cape Endaiadere (Lee, 1946).

HABITAT:

Total collections, 37

Habitat	*Number of collections*	*Habitat index*
Artificial containers	25	68
Coconut shells	5	13
Tree holes	5	13
Leaf axils	2	5

*p*H, 18 readings

Range	4.0–6.5
Mode	5.0
Average	5.4

Factor	*Percentage occurrence*
Shaded	76
Exposed	24
Temporary	100
Clear	51
Stagnant	42
Polluted	7
Vegetation Absent	100

Taylor (1934) found *bimaculipes* in cut ends of bamboo, and Lee (1946) found it in hollow logs, tree holes, artificial containers, and coconut shells. In our surveys it occurred frequently (84 per cent) in mixed collections. Percentages of associated species were: *A. albolineatus*, 19; *A. scutellaris*, 14; *U. nigerrima*, 11; *Toxorhynchites* spp., 7; *A. notoscriptus*, 7; *Arm. milnensis*, 5; *U. argyrotarsis*, 5; others, 16.

Tripteroides (Tripteroides) brevipalpis? Brug

Tripteroides (*Tripteroides*) *brevipalpis* Brug, 1934, Bul. Ent. Res. 25: 508.

Lee (1946) stated that two specimens from Oro Bay and several from Biak (in the University of Queensland collection) differ from *T. brevipalpis* in a few details. He believes that it would be wise to wait for more adequate material before describing this "probably new form." Miss Elizabeth Marks, University of Queensland, in a personal communication to me, states: "The specimens of *T. brevipalpis?* from Biak mentioned by Lee are your series."

DISTRIBUTION: Dutch New Guinea: Padaido Islands, called Biak by Lee in the above discussion (Author). Northeast New Guinea: Finschhafen (W. M. Rogoff). Papua: Oro Bay (Lee, 1946).

HABITAT:

Total collections, 8

Habitat	*Number of collections*	*Habitat index*
Tree holes	4	50
Artificial containers	3	37
Coconut shells	1	12

*p*H, 8 readings

Range	5.0–7.0
Mode	6.0
Average	6.0

Factor	Percentage occurrence
Shaded	87
Exposed	13
Temporary	100
Clear	50
Stagnant	44
Polluted	6
Vegetation	
Absent	100

In common with all species of *Tripteroides* in our collections, *T. brevipalpis?* was limited entirely to small collections of water in containers. It was found primarily (88 per cent) in mixed collections. Percentages of associates were: *A. scutellaris*, 27; *A. albolineatus*, 27; *C. ?uniformis*, 20; *U. papua*, 14.

Harpagomyia genurostris (Leicester)

Malaya genurostris Leicester, 1908, Cul. Malaya: 258.

DISTRIBUTION: Northeast New Guinea: Saidor (Author); Alexishafen (T. K. Ruebush). Papua: Dobodura, Cape Sudest (King, 1944). Aside from the mimeographed records of King (1944), these are the first New Guinea records of this Oriental species.

HABITAT: Brug (1932) recorded larvae from the leaf axils of *Colocasia* spp., *Crinum* sp., *Susum malayanum aquatica*, and from the inflorescence of *Cyrtandra glabra*. King (1944) reported it from the leaf axil of taro (*Colocasia* sp.).

All of my eight collections were taken from leaf axils (taro, 63 per cent; banana, 37 per cent), in clear, shaded water. This species and *Aedes kochi* were the only larvae with an absolute affinity for any one habitat. *Harpagomyia genurostris* was found associated with *A. kochi* once; otherwise it occurred in pure collections.

Uranotaenia (Uranotaenia) albescens Taylor

Uranotaenia albescens Taylor, 1914, Ent. Soc. London, Trans. 1913 (Part IV): 705.

DISTRIBUTION: Papua: Milne Bay (Lee, 1944*a*; Author).

HABITAT: All New Guinea records are from surface water. Taylor (1914*c*) recorded it from clear, shallow, grassy pools, and Lee (1944*a*) added wheel ruts. My single collection was taken from a clear, sluggish, exposed running creek with abundant emergent vegetation, at a *p*H of 5, and associated with *Anopheles farauti*.

Uranotaenia (Uranotaenia) argyrotarsis Leicester

Uranotaenia argyrotarsis Leicester, 1908, Cul. Malaya: 214.

Uranotaenia argyrotarsis var. King and Hoogstraal (1946*f*: 148).

DISTRIBUTION: Dutch New Guinea: Hollandia (King and Hoogstraal, 1946*f*). Northeast New Guinea: Finschhafen, Saidor (Author). Papua: Milne Bay (Author).

HABITAT:

Total collections, 58

Habitat	Number of collections	Habitat index
Creeks: Pot holes	24	41
Swamps	9	15
Puddles	9	15
Artificial containers	6	10
Creeks: Running	5	9
Borrow pits	4	7
Ditches	1	2

*p*H, 27 readings	
Range	4.0–8.0
Mode	5.0
Average	5.5

Factor	Percentage occurrence
Shaded	63
Exposed	37
Temporary	26
Semi-permanent	50
Permanent	24
Clear	65
Muddy	7
Stagnant	26
Polluted	2
Vegetation	
Absent	51
Present	49
Sparse	27
Moderate	46
Abundant	27

Algae	28
Emergent	36
Overhanging	33
Floating	3

Argyrotarsis was quite common in my collections but apparently it has not previously been reported from either Papua or Northeast New Guinea.

It has been recorded by Taylor (1934) and by King and Hoogstraal (1946*f*) from ground pools. Ninety per cent of my collections were from surface water, but 10 per cent were from artificial containers. *Argyrotarsis* occurred mostly (71 per cent) in mixed collections. Percentages of associates were: *C. pullus*, 20; *C. halifaxi*, 13; *An. farauti*, 10; *C. fraudatrix*, 7; *Bironella* spp., 5; others, 16.

Uranotaenia (Pseudoficalbia) nigerrima Taylor

Uranotaenia nigerrima Taylor, 1914, Ent. Soc. London, Trans. 1914 (Part I): 203. Type locality: Milne Bay, Papua; Lakekamu Gold Field, Northeast New Guinea.

DISTRIBUTION: Dutch New Guinea: Pionierbivak (Bonne-Wepster, 1938), Hollandia (King and Hoogstraal, 1946*c*); Padaido Islands (A. G. Humes). Northeast New Guinea: Lakekamu Gold Field (Taylor, 1914*a*); Finschhafen, Saidor (Author). Papua: Milne Bay (Taylor, 1914*a*; Author); Mekeo District (Hill, 1925).

HABITAT:

Total collections, 56

Habitat	*Number of collections*	*Habitat index*
Artificial containers	30	54
Coconut shells	16	28
Spathes and leaves	8	14
Puddles	1	2
Ditch	1	2

*p*H, 9 readings

Range	4.0–6.5
Mode	5.5
Average	5.3

Factor	*Percentage occurrence*
Shaded	65
Exposed	35
Temporary	98
Semi-permanent	2
Clear	47
Muddy	10
Stagnant	33
Polluted	10
Vegetation	
Absent	100

Nigerrima has been recorded from fallen leaves, fallen coconut bracts, coconut shells, and tree holes (Taylor, 1934; Lee, 1944*a*; King and Hoogstraal, 1946*c*). However, my indices show that spathes and leaves were seldom utilized and that tree holes were never used. Artificial containers and coconut shells were the more important habitats. This species occurred to an approximately equal degree in pure (52 per cent) and mixed collections. Percentages of associates were: *Arm. breinli*, 9; *T. bimaculipes*, 9; *A. albolineatus*, 7; *A. scutellaris*, 6; *Toxorhynchites* spp., 6; *C. fragilis*, 6; others, 5.

Uranotaenia (Pseudoficalbia) papua Brug

Uranotaenia papua Brug, 1924, Bul. Ent. Res. 14: 441. Type locality: Pionierbivak, Dutch New Guinea.

DISTRIBUTION: Dutch New Guinea: Pionierbivak (Brug, 1924); Assike, Merauke, Tanahmerah (Bonne-Wepster, 1938); Padaido Islands (Author). Northeast New Guinea: Finschhafen, Saidor (Author). Papua: Milne Bay (Lee, 1944*a*; Author); Dobodura (King and Hoogstraal, 1946*c*).

HABITAT:

Total collections, 24

Habitat	*Number of collections*	*Habitat index*
Artificial containers	9	38
Spathes and leaves	8	33
Coconut shells	3	13
Rock holes	2	8
Tree holes	1	4
Puddles	1	4

*p*H, 5 readings

Range	4.0–5.5
Mode	5.5
Average	5.1

Factor	*Percentage occurrence*
Shaded	68
Exposed	32
Temporary	100
Clear	73
Stagnant	27
Vegetation	
Absent	100

U. papua has been reported breeding in rusty tins (Lee, 1944*a*) and in a cup fungus (King and Hoogstraal, 1946*c*). My data show that the only important habitats were artificial containers and spathes and leaves. It occurred chiefly (71 per cent) in pure collections. Percentages of associates were: *A. scutellaris*, 5; *A. albolineatus*, 4; *C. ?uniformis*, 4; *T. brevipalpis?*, 4; others, 12.

Aedes (Mucidus) aurantius chrysogaster (Taylor)

Mucidus chrysogaster Taylor, 1927, Bul. Ent. Res. 18: 67.

DISTRIBUTION: Dutch New Guinea: Padaido Islands (A. G. Humes). Northeast New Guinea: Morobe (Author). Papua: Milne Bay (Author). These are the first records of *chrysogaster* from New Guinea.

HABITAT: *Chrysogaster* was present in five collections from temporary surface water. It occurred twice in puddles, once in a creek pot hole, once in a coral depression, and once in a small artificial hole in active use as a urinal in which the degree of pollution was obviously very high. Taylor (1927) recorded it in a shallow, semi-shaded rock pool containing a large quantity of decaying vegetable matter with *C. halifaxi*. It occurred solely in mixed collections. Associates were: *C. pullus*, *An. punctulatus*, *U. argyrotarsis*, and *C. halifaxi*.

Aedes (Finlaya) candidoscutellum Marks

Aedes (*Finlaya*) *candidoscutellum* Marks, 1947, Queensland Univ., Dept. Biol. Papers 2:1.

DISTRIBUTION: Dutch New Guinea: Hollandia (Marks, 1947*b*). Papua: Milne Bay (Marks, 1947*b*; Author).

HABITAT: Marks (1947*b*) reported this species from tree cavities, and stated that it appeared to show a preference for clear water. My two collections were both from tree holes, in clear, shaded water, associated with *A. keefei.*

Aedes (Finlaya) hollandius
King and Hoogstraal

Aedes (*Finlaya*) *hollandius* King and Hoogstraal, 1946, Wash. Ent. Soc. Proc. 48: 38. Type locality: Mount Dafonsero, near Hollandia, Dutch New Guinea.

DISTRIBUTION: Dutch New Guinea: Mount Dafonsero (King and Hoogstraal, 1946*d*); Hollandia (King and Hoogstraal, 1946*c*, *d*). Northeast New Guinea: Finschhafen (King and Hoogstraal, 1946*d*). Papua: Dobodura (King and Hoogstraal, 1946*c*, *d*); Milne Bay (Author).

HABITAT: King and Hoogstraal (1946*c*) record *hollandius* from fallen palm leaves (25 collections), tree holes (2 collections), tin cans (2 collections), and a rock pool (1 collection). I did not find *hollandius* in fallen palm leaves. In four collections it occurred twice in rock holes, once in a tree hole, and once in an artificial container. All of my collections were from temporary, clear, shaded water without vegetation. It occurred mostly (75 per cent) in mixed collections. Associates were: *A. papuensis*, *A. albolineatus*, *A. novalbitarsis*, *C. halifaxi*, and *C. fraudatrix.*

Aedes (Finlaya) keefei
King and Hoogstraal

Aedes (*Finlaya*) *keefei* King and Hoogstraal, 1946, Wash. Acad. Sci. Jour. 36: 311. Type locality: K. B. Mission, Milne Bay, Papua.

DISTRIBUTION: Papua: K. B. Mission, Sariba Island (King and Hoogstraal, 1946*a*); Milne Bay (King and Hoogstraal, 1946*a*; Author).

HABITAT:

Total collections, 11

Habitat	Number of collections	Habitat index
Tree holes	10	91
Coconut shells	1	9
*p*H, 2 readings	4.5,5.0	

Factor	Percentage occurrence
Shaded	90
Exposed	10
Temporary	100
Clear	100
Vegetation Absent	100

This uncommon species has been reported only from the Milne Bay area. King and Hoogstraal (1946*a*) recorded it from a stump hole, and in my collections it occurred almost entirely in tree holes. It was found mostly (64 per cent) in mixed collections. Percentages of associates were: *Toxorhynchites* spp., 14; *A. scutellaris*, 14; *A. albolineatus*, 14; *A. candidoscutellum*, 14; *T. bimaculipes*, 8.

Aedes (Finlaya) kochi (Dönitz)

Culex kochi Dönitz, 1901, Insekten Börse 5: 38. Type locality: "Neu-Guinea." Allotype male, Milne Bay, Papua (Marks, 1947*a*). *Aedes poicilia* (Theobald) has been recorded from New Guinea by the following: Theobald (1905); Taylor (1914*a*, *b*); Breinl (1915); Bonne-Wepster (1938). However, recent revisions by Knight and Laffoon (1946) and Marks (1947*a*) state that all Australasian records of *poicilia* undoubtedly refer to *kochi*.

DISTRIBUTION: Dutch New Guinea: Fakfak (Bonne-Wepster, 1938); Merauke (Marks, 1947*a*); Amsterdam Island (Author). Northeast New Guinea: Madang, Seleo, Berlinhafen, Mount Hanseman, Astrolabe Bay (Theobald, 1905); Lakekamu Gold Field (Taylor, 1914*a*; Breinl, 1915); Draeger Harbor, Cape Cretin (Edwards, 1926); Bulwa (Taylor, 1934); Finschhafen (Mackerras, 1946); Lae (Mackerras, 1946; Marks, 1947*a*); Saidor (Author). Papua: Samarai Island, Mekeo District (Taylor, 1914*a*); Karema (Taylor, 1914*b*); Wasima Island, Yule Island (Hill, 1925); Milne Bay (Marks, 1947*a*; Author).

HABITAT:

Total collections, 45

Habitat	Number of collections	Habitat index
Leaf axils	45	100
Banana (37 per cent)		
Pandanus (30 per cent)		
Taro (29 per cent)		
Pineapple (4 per cent)		
*p*H, 16 readings		
Range	4.0–6.0	
Mode	5.5	
Average	5.4	

Factor	Percentage occurrence
Shaded	49
Exposed	51
Temporary	100
Clear	85
Stagnant	15
Vegetation Absent	100

A. kochi and *Harpagomyia genurostris* were the only species with an absolute affinity for any one habitat. Both were found solely in leaf axils of various plants. *Kochi* occurred to approximately the same extent in *Pandanus*, taro, and banana, and much more rarely in pineapple plants. This corresponds roughly to the relative abundance of these plants in the areas studied. At Amsterdam Island an index of its incidence in *Pandanus* was determined. All leaf axils containing water in 100 scattered *Pandanus* trees were examined and *kochi* was found in only 2 per cent.

It has been reported to breed in half coconuts (Hill, 1925; Stone and Bohart, 1944) and in leaf axils of *Pandanus*, banana, taro, cunjevoi, *Crinum*, pineapple (Heydon, 1931; Taylor, 1934, 1943; Stone and Bohart, 1944; Marks, 1947*a*). It is significant that *Pandanus* and taro leaf axils are mentioned in almost every habitat reference; banana is omitted in all except one. Yet my collections from banana axils were the most numerous. Similarly, although coconut shells are mentioned in the literature, Taylor (1943) did not find *kochi* among any of the thousands of mosquitoes taken from coconut shells. And *kochi* was not collected from any of the 174 coconut shells which I examined.

It occurred primarily (86 per cent) in pure collections but was collected with *T. bimaculipes*, *U. papua*, *H. genurostris*, and *A. scutellaris*.

Aedes (Finlaya) notoscriptus (Skuse)

Culex notoscriptus Skuse, 1889, Linn. Soc. N. S. Wales, Proc. (2d series) 3: 1738.

DISTRIBUTION: Dutch New Guinea: Merauke (Brug, 1934; Bonne-Wepster, 1938); Toerai (Bonne-Wepster, 1938); Hollandia (King and Hoogstraal, 1946*a*, *c*, *f*); Amsterdam Island (Author); Padaido Islands (A. G. Humes). Northeast New Guinea: Muina, Seleo, Berlinhafen, Madang, Ragetta Island (Theobald, 1905); Lakekamu Gold Field (Breinl, 1915); Finschhafen, Saidor (Author). Papua: Milne Bay (Taylor, 1914*a*; Author); Dobodura (King and Hoogstraal, 1946*c*).

HABITAT:

Total collections, 47

Habitat	*Number of collections*	*Habitat index*
Tree holes	24	51
Artificial containers	16	34
Coconut shells	6	13
Rock holes	1	2

*p*H, 20 readings

Range	4.0–6.5
Mode	4.5
Average	5.1

Factor	*Percentage occurrence*
Shaded	72
Exposed	28
Temporary	100
Clear	63
Stagnant	37
Vegetation	
Absent	94
Present, algae	6

The innumerable references to collections of *notoscriptus* in Australia state that tree holes and artificial containers are the most commonly utilized habitats. My collections further bear out the importance of these two habitats.

In New Guinea, King and Hoogstraal (1946*a*, *c*) recorded *notoscriptus* taken from fallen palm leaves, tin cans, and tree holes with *A. plumiferus*, *A. albolineatus*, and *Toxorhynchites splendens*, and Brug (1934) recorded it from tree holes. However, in my collections it was absent from fallen bracts and leaves. It occurred mostly (60 per cent) in pure collections. Percentages of associates were: *A. albolineatus*, 9; *T. bimaculipes*, 5; *Arm. breinli*, 5; *C. fragilis*, 5; others, 16.

Aedes (Finlaya) novalbitarsis
King and Hoogstraal

Leucomyia albitarsis Taylor, 1914, Ent. Soc. London, Trans. 1914 (Part I): 194. [Nec *Anisocheleomyia albitarsis* Ludlow, Canad. Ent. 37: 131 = *Aedes* (*Stegomyia*) *desmotes* (Giles), 1904; synonymy by Edwards, 1922, Indian Jour. Med. Res. 10: 464.] Type locality: Lakekamu Gold Field, Northeast New Guinea.

Aedes (*Finlaya*) *novalbitarsis* new name King and Hoogstraal, 1946, Wash. Ent. Soc. Proc. 48: 146.

DISTRIBUTION: Dutch New Guinea: Hollandia (King and Hoogstraal, 1946*c*, *f*); Padaido Islands (Author). Northeast New Guinea: Lakekamu Gold Field (Taylor, 1914*a*); Finschhafen (King and Hoogstraal, 1946*c*). Papua: Dobodura, Oro Bay (King and Hoogstraal, 1946*c*); Milne Bay (Author).

HABITAT:

Total collections, 12

Habitat	*Number of collections*	*Habitat index*
Rock holes	6	50
Puddles	5	42
Tree holes	1	8

*p*H, 5 readings

Range	5.0–6.0
Mode	5.0
Average	5.2

Factor	*Percentage occurrence*
Shaded	50
Exposed	50
Temporary	100
Clear	72
Muddy	14
Stagnant	14
Vegetation	
Absent	75
Present	25
Sparse	67
Abundant	33
Algae	67
Overhanging	33

In 49 collections, King and Hoogstraal (1946*c*) obtained 31 from tree holes, artificial containers, and rock holes, and they listed palm bracts, coconut leaves and husks, and a sea shell as occasional habitats. In contrast, 50 per cent of our collections were from rock holes, 42 per cent from puddles, only 8 per cent from tree holes, and none from artificial containers. King and Hoogstraal (1946*c*) give a very long list of associated species. In our surveys, *novalbitarsis* occurred mostly (67 per cent) in pure collections. Associated species were: *An. punctulatus*, *A. papuensis*, *A. notoscriptus*, *C. halifaxi*, and *A. hollandius*.

Aedes (Finlaya) papuensis (Taylor)

Leucomyia australiensis var. *papuensis* Taylor, 1914, Ent. Soc. London, Trans. 1914 (Part I): 193. Type locality: Milne Bay, Papua.

DISTRIBUTION: Dutch New Guinea: Albatrosbivak (Brug, 1927; Bonne-Wepster, 1938); Doromena (King and Hoogstraal, 1946*c*); Padaido Islands (A. G. Humes). Northeast New Guinea: Lakekamu Gold Field (Breinl, 1915); Finschhafen (King and Hoogstraal, 1946*c*; Author); Gusiko (King and Hoogstraal, 1946*c*); Morobe (Author). Papua: Milne Bay (Taylor, 1914*a*; Author); Higatura (King and Hoogstraal, 1946*c*).

HABITAT:

Total collections, 61

Habitat	*Number of collections*	*Habitat index*
Rock holes	23	38
Puddles	16	26
Artificial containers	9	15
Tree holes	6	10
Coconut shells	5	8
Borrow pits	2	3

*p*H, 9 readings

Range	5.0–6.5
Mode	6.0
Average	5.2

Factor	*Percentage occurrence*
Shaded	46
Exposed	54
Temporary	96
Semi-permanent	4
Clear	62
Muddy	21
Stagnant	17
Vegetation	
Absent	85
Present	15
Moderate	67
Abundant	33
Algae	84
Floating	16

A. papuensis has been recorded from rock pools, tree holes, on paper, drum heads, sunlit ruts, sunlit coral pools (Lee, 1944*a*; King and Hoogstraal, 1946*c*).

A. papuensis and *A. novalbitarsis* were the only *Aedes* with high habitat indices for both surface water and water in containers, and the only *Aedes* with fairly high indices for puddles. *Papuensis* occurred mostly (64 per cent) in mixed collections. Percentages of associates were: *A. albolineatus*, 8; *C. pullus*, 8; *C. halifaxi*, 8; *An. punctulatus*, 6; *Toxorhynchites* spp., 5; others, 29.

Aedes (Finlaya) wallacei Edwards

Aedes wallacei Edwards, 1926, Bul. Ent. Res. 17: 105.

DISTRIBUTION: Dutch New Guinea: Assike, Merauke, Sorong, Tanahmerah (Bonne-Wepster, 1938); Hollandia (King and Hoogstraal, 1946*c*). Northeast New Guinea: Draeger Harbor, Cape Cretin (Edwards, 1926); Bulwa (Taylor, 1934); Lae (Marks, 1947*a*). Papua: Wasima Island, Yule Island (Hill, 1925); Lalapipi, Dobodura (Marks, 1947*a*); Milne Bay (Marks, 1947*a*; Author).

HABITAT: *Wallacei* has been recorded from leaf axils of banana, taro, pineapple, and *Pandanus*, and from fallen palm leaves (Taylor, 1934; King and Hoogstraal, 1946*c*; Marks, 1947*a*).

My three collections were all from leaf axils—two from pineapple and one from *Pandanus*—in clear, shaded water. *Wallacei* occurred once in a pure collection, once with *U. papua*, and once with *T. bimaculipes*.

Aedes (Skusea) dasyorrhus
King and Hoogstraal

Aedes (*Skusea*) *dasyorrhus* King and Hoogstraal, 1946, Ent. Soc. Wash. Proc. 48 (4): 100. Type locality: Cape Tjeweri, Jatufa Bay, Hollandia, Dutch New Guinea.

DISTRIBUTION: Dutch New Guinea: Hollandia, Biak (King and Hoogstraal, 1946*e*). Papua: Milne Bay (Author).

HABITAT: *Dasyorrhus* has been reported by King and Hoogstraal (1946*e*) from cans at the edge of a mangrove swamp, possibly with partially salt water, and from a metal container.

Our five collections were all from holes in low, horizontally placed tree trunks extending out over the waters of Milne Bay and obviously receiving salt water spray. Three salinity readings showed 30, 50, and 65 per cent of sea water. *A. dasyorrhus* and *C. sitiens* were the only species collected from this very unusual habitat. *Dasyorrhus* occurred primarily in exposed, clear water with sparse amounts of algae, and always in pure collections.

Aedes (Stegomyia) albolineatus
(Theobald)

Scuteomyia albolineata Theobald, 1904, Entomologist 37: 77.

DISTRIBUTION: Dutch New Guinea: Hollandia (Knight and Rozeboom, 1946; King and Hoogstraal, 1946*a*, *c*); Toem (Knight and Rozeboom, 1946); Padaido Islands, Amsterdam Island (Author). Northeast New Guinea: Finschhafen, Saidor (Knight and Rozeboom, 1946; Author); Morobe (Author). Papua: Dobodura (Knight and Rozeboom, 1946); Milne Bay (Knight and Rozeboom, 1946; Author).

HABITAT:

Total collections, 71

Habitat	*Number of collections*	*Habitat index*
Tree holes	37	52
Coconut shells	18	25
Artificial containers	11	16
Leaf axils	2	3
Rock holes	2	3
Swamp	1	1

*p*H, 44 readings

Range	4.5–7.0
Mode	5.0
Average	5.6

Factor	*Percentage occurrence*
Shaded	95
Exposed	5
Temporary	99
Permanent	1
Clear	52
Muddy	4
Stagnant	42
Polluted	2
Vegetation	
Absent	100

Albolineatus and *A. scutellaris* were the only species present in every area studied.

Taylor (1934), Lee (1944*a*), and Knight and Rozeboom (1946) record *albolineatus* from tree holes, coconut shells, artificial containers, leaf axils, fallen leaves, and rock pools. My habitat indices are in agreement with the literature and demonstrate the high affinity of *albolineatus* for tree holes.

Albolineatus occurred almost equally in pure (44 per cent) and in mixed (56 per cent) collections. Percentages of associated species were: *A. scutellaris*, 11; *T. bimaculipes*, 7; *A.*

notoscriptus, 6; *A. papuensis*, 5; *Toxorhynchites* spp., 4; *U. nigerrima*, 4; *C. fragilis*, 4; *T. brevipalpis?*, 4; others, 11.

Aedes (Stegomyia) scutellaris (Walker)

Culex scutellaris Walker, 1859, Linn. Soc. London, Proc. 3: 79. Type locality: Aru Islands.

Culex zonatipes Walker (1861: 229). Synonymy in Stone (1947: 85).

Aedes (*Stegomyia*) *variegatus* Doleschall. Hill (1925: 70); Bonne-Wepster and Brug (1932: 83).

Aedes (*Stegomyia*) *hebrideus* Edwards. Farner and Bohart (1945: 46).

Aedes scutellaris scutellaris King and Hoogstraal (1946*c*: 154); Forbes and Horsfall (1947: 602–603).

Aedes (*Stegomyia*) *scutellaris* Walker. Stone (1947: 85). A topotypic male: Dobo, Aru Islands.

DISTRIBUTION: Dutch New Guinea: Aru Islands (Walker, 1859); Dore (Walker, 1861); Fakfak (Bonne-Wepster, 1938); Doromena (King and Hoogstraal, 1946*c*); Hollandia (King and Hoogstraal, 1946*c*; Toffaleti and King, 1947; Forbes and Horsfall, 1947); Biak (Forbes and Horsfall, 1947); Padaido Islands, Amsterdam Island (Penn, 1947*a*; Author). Northeast New Guinea: Seleo, Berlinhafen, Astrolabe Bay, Bogadjim, Muina (Theobald, 1905); Lakekamu Gold Field (Taylor, 1914*a*; Breinl, 1915); Madang (Hill, 1925); Wau, Salamaua, Bulwa, Bulolo (Taylor, 1934); Saidor (Farner and Bohart, 1945; Penn, 1947*a*; Author); Draeger Harbor (Penn, 1947*a*); Lae (Mackerras, 1946); Finschhafen (Mackerras, 1946; Author); Morobe (Author). Papua: Boirawe, Samarai, Kaile, Yule Island, Wasima (Hill, 1925); Cape Endaiadere (Farner and Bohart, 1945); Milne Bay (Farner and Bohart, 1945; Mackerras, 1946; Penn, 1947*a*; Author); Dobodura (King and Hoogstraal, 1946*c*, *f*); Oro Bay (Forbes and Horsfall, 1947); Moresby (Hill, 1925; Mackerras, 1946).

Taylor (1914*b*) and Breinl (1915) recorded *Stegomyia pseudoscutellaris* Theobald from Samarai Island, Papua. This record probably refers to *A. scutellaris*, since this locality would extend the range of *pseudoscutellaris*—as defined by Farner and Bohart (1945)—several thousand miles westward.

HABITAT: The majority of these data have previously been given by Penn (1947*a*).

Total collections, 251

Habitat	*Number of collections*	*Habitat index*
Artificial containers	114	45
Coconut shells	80	32
Tree holes	27	11
Puddles	15	6
Spathes and leaves	11	4
Leaf axils	3	1
Wells	1	0

*p*H, 172 readings

Range	4.5–8.0
Mode	6.5
Average	6.1

Factor	*Percentage occurrence*
Shaded	66
Exposed	34
Temporary	93
Permanent	7
Clear	45
Muddy	12
Stagnant	41
Polluted	2
Vegetation	
Absent	94
Present, algae	6

Along with *A. albolineatus*, *scutellaris* was present in my collections in every area studied, and ranked second only to *C. pullus* in number of collections.

Brief mention of habitats utilized has been given by Hill (1925), Bonne-Wepster and Brug (1932, 1937, 1939), Taylor (1934), Lee (1944*a*), Farner and Bohart (1945), and King and Hoogstraal (1946*c*). Tree holes, coconut shells, and artificial containers are the habitats most commonly recorded, but fallen leaves, forest pools, and rock holes have also been mentioned.

After its role as a dengue vector was established (Daggy, 1945; Mackerras, 1946) rather detailed studies of the biology of *A. scutellaris* were published by Mackerras (1946), Forbes and Horsfall (1947), and Penn (1947*a*). All detailed studies have demonstrated that artificial containers are the primary habitat of this important dengue vector.

Scutellaris occurred mostly (73 per cent) in pure collections. The main associate was *A. albolineatus* (6 per cent), but there was an extremely long list of 20 other associates which has been given by Penn (1947*a*).

Aedes (Aedimorphus) vexans (Meigen)

Culex vexans Meigen, 1830, Syst. Bechr. 6: 241.

DISTRIBUTION: Dutch New Guinea: Merauke (Bonne-Wepster, 1938). Northeast New Guinea: Finschhafen, Saidor (Author). Papua: Milne Bay (Lee, 1944*a*; Author).

HABITAT:

Total collections, 12

Habitat	*Number of collections*	*Habitat index*
Puddles	11	92
Borrow pits	1	8
*p*H, one reading	6.5	

Factor	*Percentage occurrence*
Shaded	28
Exposed	72
Temporary	92
Semi-permanent	8
Clear	89
Muddy	11
Vegetation	
Absent	57
Present	43
Moderate	100
Emergent	67
Overhanging	33

Vexans was widely distributed but an uncommon species. The above records are the first for Northeast New Guinea. My limited data and records of Bonne-Wepster and Brug (1937, 1939) and Lee (1944*a*) show that it is exclusively a surface breeder. However, Bonne-Wepster and Brug (1939) found it in fresh, brackish, and salt water, whereas my specimens were entirely from fresh water. It occurred primarily (75 per cent) in mixed collections. Percentages of associates were: *An. punctulatus*, 25; *C. pullus*, 17; others, 33.

Aedes (Aedes) funereus (Theobald)

Skusea funerea Theobald, 1903, Mon. Cul. 3: 292.

DISTRIBUTION: Dutch New Guinea: Wamal, Tanahmerah, Merauke, Assike (Bonne-Wepster, 1938); Hollandia (Toffaleti and King, 1947). Northeast New Guinea: Saidor, Finschhafen (Author). Papua: Mekeo District (Taylor, 1914*a*; Edwards, 1924); Milne Bay (King and Hoogstraal, 1947; Author).

HABITAT:

Total collections, 7

Habitat	*Number of collections*	*Habitat index*
Puddles	3	43
Swamps	2	29
Pond	1	14
Borrow pit	1	14
*p*H, one reading	5.0	

Factor	*Percentage occurrence*
Shaded	71
Exposed	29
Temporary	86
Permanent	14
Clear	86
Muddy	14
Vegetation	
Absent	33
Present	67
Abundant	100
Overhanging	100

These records from Saidor and Finschhafen are the first from Northeast New Guinea. Hill (1922) recorded it in an algae- and grass-covered seepage, in fresh water pools, and in salt puddles in mangrove swamps. Lee (1944*a*) lists it from fresh water swamps. In my collections also, *funereus* occurred in surface water only, and was never found in salt or brackish water. It occurred mostly in mixed (57 per cent) collections. Percentages of associates were: *An. punctulatus*, 16; *C. pullus*, 10; others, 31.

Aedes (Aedes) lineatus (Taylor)

Skusea funerea Theo. var. *ornata* Theobald, 1905, Mus. Nat. Hungarici Ann. 3: 79. [Nec *Culex ornatus* Meigen, 1818 = *A.* (*Finlaya*) *geniculatus* Oliver, 1791. Synonymy by Edwards, 1921, Bul. Ent. Res. 12: 319.]

Lepidotomyia lineatus Taylor, 1914, Ent. Soc. London, Trans. 1914 (Part I): 191. Type locality: Lakekamu Gold Field, Northeast New Guinea; Mekeo, Papua.

Aedes ornatus Theobald. King and Hoogstraal (1946*c*: 118); Toffaleti and King (1947).

Aedes (*Aedes*) *lineatus* (Taylor). King and Hoogstraal (1947: 118).

DISTRIBUTION: Dutch New Guinea: Toerai, Tanahmerah, Merauke, Assike (Bonne-Wepster, 1938); Hollandia (King and Hoogstraal, 1946*c*; Toffaleti and King, 1947). Northeast New Guinea: Satelberg Mt., Madang (Theobald, 1905); Lakekamu Gold Field (Taylor, 1914*a*); Finschhafen, Saidor (Author). Papua: Mekeo District (Taylor, 1914*a*; Edwards, 1924); Port Moresby (Lee, 1944*a*; Mackerras, 1946); Milne Bay (Author).

HABITAT:

Total collections, 7

Habitat	*Number of collections*	*Habitat index*
Puddles	4	57
Creeks: Pot holes	1	14
Swamps	1	14
Rock hole	1	14
*p*H, one reading	6.5	

Factor	*Percentage occurrence*
Shaded	29
Exposed	71
Temporary	72
Semi-permanent	14
Permanent	14
Clear	86
Muddy	14
Vegetation	
Absent	33
Present	67
Sparse	50
Abundant	50
Algae	67
Emergent	33

All literature records (Hill, 1925; Taylor, 1934; Bonne-Wepster and Brug, 1937; Lee, 1944*a*) are from surface water. Likewise, my collections were entirely from surface water. *Lineatus* occurred mostly (86 per cent) in mixed collections. *An. farauti* was the only common (21 per cent) associate.

Aedes (Aedes) parasimilis
King and Hoogstraal

Aedes (*Aedes*) *parasimilis* King and Hoogstraal, 1947, Wash. Acad. Sci. Jour. 37: 125. Type locality: Hollandia, Dutch New Guinea.

Aedes (*Aedes*) *similis* Theobald. Lee (1944*a*: 78). Synonymy in King and Hoogstraal (1947: 125).

DISTRIBUTION: Dutch New Guinea: Hollandia (King and Hoogstraal, 1947); Padaido Islands (A. G. Humes). Northeast New Guinea: Finschhafen (King and Hoogstraal, 1947; Author); Morobe (Author). Papua: Dobodura (King and Hoogstraal, 1947); Milne Bay (Lee, 1944*a*; King and Hoogstraal, 1947; Author).

HABITAT: Lee (1944*a*) reported *parasimilis* from clear pools in marshes, and King and Hoogstraal (1947) reported it from a crayfish hole and from pools at the edge of a swamp. In my five collections it also occurred entirely in surface water, three times from puddles, once from a rock hole, and once from a creek pot hole. The majority of the collections were taken from clear, temporary, shaded water. It occurred mostly (80 per cent) in mixed collections. Percentages of associates were: *C. pullus*, 22; *C. halifaxi*, 14; others, 44.

Aedes (Leptosomatomyia) aurimargo
Edwards

Aedes (*?Skusea*) *aurimargo* Edwards, 1922, Bul. Ent. Res. 13: 94.

Leptosomatomyia lateralis Theobald [nec Meigen] (1905: 110).

Aedes (*Leptosomatomyia*) *lateralis* Theobald [nec Meigen]. Edwards (1924).

DISTRIBUTION: Dutch New Guinea: Hollandia (King and Hoogstraal, 1946*c*). Northeast New Guinea: Muina (Theobald, 1905; Edwards, 1924); Finschhafen (Penn, 1947*b*; Author); Lae (Mackerras, 1946).

HABITAT: Of the four collections of *aurimargo*, three were from coconut shells and one from a tree hole. It occurred usually in clear, shaded water and always without vegetation. *Aurimargo* occurred entirely in mixed collections, twice with *Toxorhynchites* spp. and once each with *T. bimaculipes*, *A. scutellaris*, *A. albolineatus*, and *T. argenteiventris*.

Armigeres (Armigeres) breinli (Taylor)

Neosquamomyia breinli Taylor, 1914 (female only), Ent. Soc. London, Trans. 1914 (Part I): 186. Type locality: Milne Bay, Papua.

DISTRIBUTION: Dutch New Guinea: Fakfak (Brug, 1934; Bonne-Wepster, 1938); Hollandia (King and Hoogstraal, 1946*f*); Padaido Islands (Author). Northeast New Guinea: Lae (Lee, 1944*b*; Mackerras, 1946); Finschhafen (Mackerras, 1946; Author); Morobe (Author). Papua: Milne Bay (Taylor, 1914*a*; Lee, 1944*b*; Author); Oro Bay, Dobodura (Lee, 1944*b*).

HABITAT:

Total collections, 32

Habitat	*Number of collections*	*Habitat index*
Coconut shells	30	94
Spathes and leaves	1	3
Artificial containers	1	3

*p*H, 14 readings	
Range	4.5–7.5
Mode	4.5
Average	5.2

Factor	*Percentage occurrence*
Shaded	25
Exposed	75
Temporary	100
Clear	9
Muddy	33
Stagnant	16
Polluted	42
Vegetation	
Absent	100

Breinli has been reported from tree holes, coconut shells, and artificial containers, and with *Arm. milnensis* and *C. fragilis* from putrid water in tips of fallen betel nut palms (King and Hoogstraal, 1946*f*). All of the above habitats are represented in my collections. The habitat index of 94 for coconut shells calculated for *breinli* ranks second only to that for *A. kochi* and *H. genurostris*, each of which had an index of 100 for leaf axils. *Breinli* occurred frequently in very highly polluted coconut shells with a strikingly foul smell.

It was collected mostly (86 per cent) in pure collections and in tremendous concentrations of individuals. Associates were: *U. nigerrima*, 4 per cent, and others, 10 per cent.

Arm. breinli and *Arm. milnensis* were undoubtedly the most spectacular species collected, because of their large size and the great concentration of individuals, often in a minute amount of putrid, semi-liquid material.

Armigeres (Armigeres) milnensis Lee

Armigeres milnensis Lee, 1944, Linn. Soc. N. S. Wales, Proc. 69: 215. Type locality: Milne Bay, Papua.

Neosquamomyia breinli Taylor [type male only] (1914*a*: 186).

Armigeres ?breinli Taylor. Hill (1925: 70).

Armigeres obturbans var? Edwards. Lee (1944*a*: 83).

DISTRIBUTION: Dutch New Guinea: Hollandia (King and Hoogstraal, 1946*c*, *f*). Northeast New Guinea: Lakekamu Gold Field (Taylor, 1914*a*; Lee, 1944*b*); Lae (Lee, 1944*b*; Mackerras, 1946); Finschhafen (Mackerras, 1946); Morobe (Author). Papua: Mekeo District (Hill, 1925; Lee, 1944*b*); Bulldog, Lalapipi (Lee, 1944*b*); Milne Bay (Edwards, 1924; Lee, 1944*b*; Author).

HABITAT:

Total collections, 38

Habitat	*Number of collections*	*Habitat index*
Coconut shells	19	50
Artificial containers	9	24
Tree holes	7	18
Borrow pits (one was a urinal pit)	3	8

*p*H, 11 readings

Range	4.0–7.0
Mode	6.5
Average	5.8

Factor	*Percentage occurrence*
Shaded	43
Exposed	57
Temporary	92
Semi-permanent	8
Clear	20
Muddy	11
Stagnant	32
Polluted	37
Vegetation	
Absent	100

Hill (1925) records *milnensis* from tree holes, Lee (1944*a*) from coconut shells, and King and Hoogstraal (1946*c*) report it associated with *Arm. breinli* and *C. fragilis* in putrid water in tips of fallen betel nut palms. My collections demonstrate the importance of coconut shells. However, *milnensis* utilized this habitat to a lesser degree (50) than did *breinli* (94).

As with *breinli*, the present species often occurred in polluted water and in great concentrations of individuals. In one collection the larvae were found in dense masses in a small pit filled with urine. Feng (1938*b*) states that in China the usual habitat of *Arm. obturbans* is tubs of fermenting urine. *Milnensis* occurred mostly (84 per cent) in pure collections. Percentages of associates were: *Arm. breinli*, 3; *T. bimaculipes*, 3; *A. scutellaris*, 3; others, 7.

Culex (Lutzia) halifaxi Theobald

Culex halifaxi Theobald, 1903, Mon. Cul. 3: 231.

DISTRIBUTION: Dutch New Guinea: Albatrosbivak (Brug, 1927; Bonne-Wepster, 1938); Manokwari (Brug and Haga, 1923); Toerai (Brug and Haga, 1923; Bonne-Wepster, 1938); Assike, Fakfak, Merauke, Tanahmerah (Bonne-Wepster, 1938); Hollandia (King and Hoogstraal, 1946*b*, *f*); Padaido Islands (Author). Northeast New Guinea: Finschhafen, Saidor, Morobe (Author). Papua: Mekeo District (Hill, 1925); Milne Bay (Author).

HABITAT:

Total collections, 183

Habitat	*Number of collections*	*Habitat index*
Puddles	118	65
Artificial containers	26	14
Creeks: Pot holes	22	12
Ditches	5	3
Borrow pits	5	3
Rock holes	2	1
Pond	1	–
Swamp	1	–
Well	1	–
Coconut shell	1	–
Tree holes	1	–

*p*H, 31 readings

Range	4.0–8.0
Mode	6.5
Average	6.0

Factor	*Percentage occurrence*
Shaded	32
Exposed	68
Temporary	81
Semi-permanent	17
Permanent	2
Clear	41
Muddy	28
Stagnant	25
Polluted	6
Vegetation	
Absent	68
Present	32
Sparse	33
Moderate	45
Abundant	22
Algae	59
Emergent	24
Overhanging	11
Floating	4
Submerged	2

Halifaxi was common in every locality studied and ranked third in total number of collections. These are apparently the first records from Northeast New Guinea.

Hill (1925), Bonne-Wepster and Brug (1937), and Lee (1944*a*) list a great variety of habitats: wells, marshes, jungle pools, roadside ditches, tree holes, swamps, rock pools, wheel ruts, slit trenches, and artificial containers. However, Bonne-Wepster and Brug (1939) record *halifaxi* mostly from "earthbound" breeding places, and King and Hoogstraal (1946*b*, *f*) mention only pools. In my collections it was found also in a great variety of habitats, but the figure (65 per cent) for puddles far surpasses that of any other habitat.

It occurred mostly (82 per cent) in mixed collections. Percentages of associates were: *C. pullus*, 25; *An. punctulatus*, 14; *An. farauti*, 11; *U. argyrotarsis*, 6; *C. annulirostris*, 6; *C. papuensis*, 5; others, 15.

Culex (Neoculex) brevipalpis (Giles)

Stegomyia brevipalpis Giles, 1902, Handbook Gnats, 2d ed., p. 384.

DISTRIBUTION: Dutch New Guinea: Hollandia (King and Hoogstraal, 1946*c*, *f*). Papua: Milne Bay (Author).

HABITAT: *Brevipalpis* is a rare species and the above record is the first from Papua. Both of my collections were from tree holes. One was from clear, exposed water; the other from clear, stagnant, shaded water. It was found with *Aedes papuensis* and *Aedes scutellaris*. Brug (1932) and King and Hoogstraal (1946*c*) have also recorded *brevipalpis* from tree holes.

Culex (Lophoceratomyia) fraudatrix (Theobald)

Lophoceratomyia fraudatrix Theobald, 1905, Mus. Nat. Hungarici Ann. 3: 94. Type locality: Madang and Bogadjim, Northeast New Guinea.

DISTRIBUTION: Dutch New Guinea: Assike, Tanahmerah (Bonne-Wepster, 1938); Hollandia (T. K. Ruebush). Northeast New Guinea: Madang, Bogadjim (Theobald, 1905); Finschhafen, Saidor (Author). Papua: Milne Bay (Author).

HABITAT:

Total collections, 37

Habitat	*Number of collections*	*Habitat index*
Swamps	9	24
Creeks: Pot holes	9	24
Puddles	6	16
Ponds	4	11
Creeks: Running	3	8
Artificial containers	3	8
Rock holes	1	3
Ditch	1	3
Spathes and leaves	1	3

*p*H, 14 readings

Range	4.5–8.0
Mode	5.0
Average	5.6

Factor	*Percentage occurrence*
Shaded	76
Exposed	24
Temporary	30
Semi-permanent	27
Permanent	43
Clear	73
Muddy	1
Stagnant	26
Vegetation	
Absent	44
Present	56
Sparse	15
Moderate	55
Abundant	30
Algae	21
Emergent	28
Overhanging	37
Submerged	7
Floating	7

It is rather surprising that this common species has not been previously recorded from Papua.

Lee (1944*a*) reported *fraudatrix* from shallow wells. Knight *et al.* (1944) list it from leafy pools, footprints, and brackish mangrove or fresh water pot holes. My collections also were mostly from surface water but they were not collected in brackish situations.

Culex fraudatrix was one of the few species found to a high degree in permanent water collections, and one of the very few occurring in a significant measure in extensive swampy areas. It was found mostly (84 per cent) in mixed collections. Percentages of associates were: *An. farauti*, 26; *U. argyrotarsis*, 17; *An. punctulatus*, 7; *Bironella* spp., 7; *C. annulirostris*, 6; *An. bancrofti pseudobarbirostris*, 6; *C. halifaxi*, 4; others, 11.

Culex (Lophoceratomyia) uniformis Theobald

Culex uniformis Theobald, 1905, Bombay Nat. Hist. Soc. Jour. 16: 245.

A limited number of specimens closely resembling *C. uniformis* were collected from Woendi Island. Since no recent comprehensive comparative study of the subgenus *Lophoceratomyia* has been undertaken and since, apparently, all definite records of *uniformis* are limited to the Indian Region, it seems best to note that my material was similar in a general way to *uniformis*. My specimens, which have been placed in the U. S. National Museum, may properly represent an undescribed species.

DISTRIBUTION: Dutch New Guinea: Hollandia (King and Hoogstraal, 1946*c*); Padaido Islands (Author).

HABITAT: The four collections of this species were from temporary water: two from artificial containers, one from a tree hole, and one from a puddle. It was found to the same extent in shaded and exposed, clear and stagnant water. Algae were present in one collection. *Uniformis?* was always in mixed collections with *A. scutellaris*, *T. brevipalpis?*, *U. papua*, *A. albolineatus*, and *C. pullus*.

Culex (Culiciomyia) fragilis Ludlow

Culex fragilis Ludlow, 1903, N. Y. Ent. Soc. Jour. 11: 142.

Culex (*Culiciomyia*) *papuensis* of Lee [nec Taylor] (1944*a*: 96). Synonymy in King and Hoogstraal (1946*f*: 148).

DISTRIBUTION: Dutch New Guinea: Hollandia (King and Hoogstraal, 1946*f*); Padaido Islands (Author). Northeast New Guinea: Finschhafen, Saidor (Author). Papua: Milne Bay (Lee, 1944*a*; Author).

HABITAT:

Total collections, 80

Habitat	*Number of collections*	*Habitat index*
Artificial containers	50	63
Coconut shells	9	11
Puddles	8	10
Creek: Pot holes	4	5
Tree holes	3	4
Ponds	2	2
Spathes and leaves	1	1
Rock holes	1	1
Ditch	1	1
Creek: Running	1	1

*p*H, 40 readings

Range	5.0–7.0
Mode	6.0
Average	5.8

Factor	*Percentage occurrence*
Shaded	62
Exposed	38
Temporary	90
Semi-permanent	6
Permanent	4
Clear	12
Muddy	24
Stagnant	21
Polluted	43
Vegetation	
Absent	92
Present	8
Sparse	84
Moderate	16
Algae	63
Emergent	12
Submerged	25

The records given here are apparently the first for Northeast New Guinea.

King and Hoogstraal (1946*f*) stated that, of 62 larval collections, about half were taken from temporary and semi-permanent ground pools, especially with stagnant, more or less foul or algae-filled water, in all degrees of shade, whereas the others were obtained from tree holes and artificial containers, usually with rotting vegetation and in shade. Three collections were made from putrid water in the tips of fallen betel nut palms. Lee (1944*a*) recorded it from coconut shells, polluted water in tins, refuse pits, and butts of sago palms. My data show a greater use of artificial containers than is indicated in the records of King and Hoogstraal. Both surface water and water in containers were utilized but the index of 63 for artificial containers far surpasses that of any other habitat. More than half of the collections were in shade, as mentioned by King and Hoogstraal; furthermore, the figure for polluted water (43 per cent) was higher than for any other species.

Fragilis occurred mostly in mixed (63 per cent) collections. Percentages of associates were: *C. pullus*, 12; *C. halifaxi*, 10; *A. scutellaris*, 10; *A. albolineatus*, 7; *A. notoscriptus*, 5; *Toxorhynchites* spp., 4; *U. nigerrima*, 4; others, 11. This list of associates is essentially similar to that given by King and Hoogstraal (1946*f*).

Culex (Culiciomyia) papuensis (Taylor)

Melanconion papuensis Taylor, 1914, Ent. Soc. London, Trans. 1914 (Part I): 201. Type locality: Lakekamu Gold Field, Northeast New Guinea.

Culex (*Culiciomyia*) *pallidothorax* of Lee [nec Theobald] (1944*a*: 95). Synonymy in King and Hoogstraal (1946*f*: 147).

DISTRIBUTION: Dutch New Guinea: Assike, Merauke, Tanahmerah (Bonne-Wepster, 1938); Hollandia (King and Hoogstraal, 1946*f*). Northeast New Guinea: Lakekamu Gold Field (Taylor, 1914*a*); Finschhafen (Author). Papua: Dobodura (King and Hoogstraal, 1946*f*); Milne Bay (Author).

HABITAT:

Total collections, 46

Habitat	*Number of collections*	*Habitat index*
Artificial containers	18	39
Puddles	11	24
Creeks: Pot holes	8	17
Borrow pits	4	9
Ditches	3	6
Rock hole	1	2
Tree hole	1	2

*p*H, 5 readings

Range	5.0–7.0
Mode	5.5
Average	5.9

Factor	*Percentage occurrence*
Shaded	56
Exposed	44
Temporary	67
Semi-permanent	33
Clear	45
Muddy	11
Stagnant	16
Polluted	22
Vegetation	
Absent	92
Present	8
Sparse	33
Moderate	33
Abundant	33
Algae	33
Emergent	33
Overhanging	33

Lee (1944*a*) and King and Hoogstraal (1946*f*) have recorded *papuensis* from a long list of habitats which may be grouped into artificial containers of many types, tree holes, surface pools, and wells. In my collections it was one of the few species which occurred quite frequently in both surface water and in water in containers. It must be noted that the collections from creek pot holes were nearly all in polluted water from a near-by shower drain.

Papuensis was found mostly (74 per cent) in mixed collections. Percentages of associated species were: *C. pullus*, 27; *C. halifaxi*, 21; *An. punctulatus*, 5; *An. farauti*, 5; *U. argyrotarsis*, 5; others, 11. Associates given by King and Hoogstraal (1946*f*) agree only roughly with the above.

Culex (Culiciomyia) pullus Theobald

Culex pullus Theobald, 1905, Mus. Nat. Hungarici Ann. 3: 87. Type locality: Muina, Northeast New Guinea.

Culex muticus Edwards. Edwards (1924: 6). Synonymy in Edwards (1926: 121); Hill (1925: 74); Brug (1927: 358); Brug (1934: 517); Bonne-Wepster (1938: 206–212).

Culex (*Culiciomyia*) *pallidothorax* of Bonne-Wepster [nec Theobald] (1938: 206–212). Questionable synonym in King and Hoogstraal (1946*f*: 143, 149).

DISTRIBUTION: Dutch New Guinea: Merauke (Edwards, 1924; Edwards, 1926; Bonne-Wepster, 1938); Mamberano River (Edwards, 1926); Pionierbivak (Edwards, 1926; Bonne-Wepster, 1938); Albatrosbivak (Brug, 1927; Brug, 1934; Bonne-Wepster, 1938); Fakfak (Brug, 1934; Bonne-Wepster, 1938); Manokwari, Tanahmerah, Assike, Toerai (Bonne-Wepster, 1938); Hollandia (King and Hoogstraal, 1946*c*, *f*); Padaido Islands (Author). Northeast New Guinea: Muina (Theobald, 1905); Finschhafen (King and Hoogstraal, 1946*c*; Author); Saidor, Morobe (Author). Papua: Milne Bay (Lee, 1944*a*; Author).

HABITAT:

Total collections, 289

Habitat	*Number of collections*	*Habitat index*
Puddles	178	62
Artificial containers	38	13
Creeks: Pot holes	33	11
Borrow pits	12	4
Ditches	12	4
Swamps	5	2
Creeks: Running	3	1
Coconut shells	3	1
Tree holes	2	1
Marsh	1	–
Rock holes	1	–
Spathes and leaves	1	–

*p*H, 52 readings

Range	4.0–7.0
Mode	5.5
Average	5.7

Factor	*Percentage occurrence*
Shaded	33
Exposed	67
Temporary	77
Semi-permanent	20
Permanent	3
Clear	49
Muddy	20
Stagnant	24
Polluted	7
Vegetation	
Absent	61
Present	39
Sparse	29
Moderate	47
Abundant	24
Algae	46
Emergent	23
Overhanging	18
Submerged	7
Floating	6

Pullus ranked first in number of collections. It was found in every locality studied except Amsterdam Island.

It has previously been recorded from a great variety of habitats. Brug (1934) lists a beached canoe, a tree hole, a jungle pool. Lee (1944*a*) gives fresh-water wheel ruts, grassy drains, coconut shells, tarpaulins. King and Hoogstraal (1946*f*) state that, in 150 collections, 16 were from tree holes and artificial containers, the others from shaded and sunlit ground water of all types except from permanent ponds and brackish water. My collections were also from a wide range of habitats, but the index of 62 for puddles far outweighs any other habitat. *Pullus* was found most often in clear water exposed to full sunlight, where vegetation was entirely absent.

It must be emphasized that the puddles so widely used by *pullus* were, almost entirely, recently formed ruts of vehicles or footprints. Such habitats were most numerous in the low coastal strips, on the sites of abandoned coconut plantations which were the principal centers of military activity in these areas. These habitats are the source of man-made malaria now so widely discussed in the literature in connection with habitat observations on *Anopheles punctulatus* and *Anopheles farauti*. However, little mention has been made thus far of the very general occurrence of both *Culex pullus* and *Culex halifaxi* with the anophelines in such situations.

Pullus occurred mostly (76 per cent) in mixed collections. Percentages of associates were: *C. halifaxi*, 17; *An. farauti*, 15; *An. punctulatus*, 13; *U. argyrotarsis*, 6; *C. annulirostris*, 4; *C. papuensis*, 4; *C. squamosus*, 4; others, 13. King and Hoogstraal (1946*f*) give a briefer list of associates.

Culex (Acallyntrum) bicki Stone and Penn

Culex bicki Stone and Penn, 1947, Wash. Acad. Sci. Jour. 37: 89. Type locality: Toem, Dutch New Guinea.

Culex (*Acallyntrum*) *bicki* Stone and Penn (1948: 109).

DISTRIBUTION: Dutch New Guinea: Toem (Stone and Penn, 1947). Papua: Milne Bay (Stone and Penn, 1947; Author).

HABITAT: My single collection of *bicki* was a pure collection from a clear, shaded *Pandanus* leaf axil with abundant debris. Stone and Penn (1947) recorded it from sago and taro leaf axils.

Culex (Culex) annulirostris Skuse

Culex annulirostris Skuse, 1889, Linn. Soc. N. S. Wales, Proc. (2d series) 3: 1737.

DISTRIBUTION: Dutch New Guinea: Albatrosbivak (Brug, 1927; Bonne-Wepster, 1938); Assike, Merauke, Tanahmerah (Bonne-Wepster, 1938); Padaido Islands, Amsterdam Island (Author). Northeast New Guinea: Lakekamu Gold Field (Taylor, 1914*a*); Saidor (Author). Papua: Milne Bay (Author).

HABITAT:

Total collections, 64

Habitat	*Number of collections*	*Habitat index*
Puddles	48	75
Creek: Pot holes	4	6
Ditches	4	6
Borrow pits	3	5
Artificial containers	3	5
Ponds	1	2
Wells	1	2

*p*H, 18 readings

Range	5.0–7.0
Mode	5.0, 7.0
Average	6.0

Factor	*Percentage occurrence*
Shaded	96
Exposed	4
Temporary	80
Semi-permanent	17
Permanent	3
Clear	50
Muddy	21
Stagnant	26
Polluted	3
Vegetation	
Absent	57
Present	43
Sparse	25
Moderate	45
Abundant	30
Algae	74
Emergent	16
Submerged	5
Floating	5

Specific locality records for New Guinea are few, the typical reference being "along all coasts of the Australasian Region." No doubt most authors have considered it too common to merit specific records. My collections from Milne Bay are apparently the first records from Papua.

Bonne-Wepster and Brug (1937), Taylor (1943), and Lee (1944*a*) report *annulirostris* mostly from fresh surface water but also from brackish habitats. In my collections it was found almost entirely in surface water (primarily puddles, 75 per cent) but never in brackish situations. The puddles commonly utilized were usually old, large, rather deep, and well vegetated in contrast with the small, shallow, muddy, and non-vegetated puddles so often utilized by *C. pullus*, *C. halifaxi*, and *An. punctulatus*. Furthermore, in contrast with the above species, *annulirostris* was found almost entirely (96 per cent) in shade, the highest per cent recorded for any surface water species.

Annulirostris occurred mostly (74 per cent) in mixed collections. Percentages of associates were: *C. pullus*, 16; *An. punctulatus*, 16; *An. farauti*, 16; *C. halifaxi*, 13; others, 13.

Culex (Culex) fatigans Wiedemann

Culex fatigans Wiedemann, 1823, Aussereur. Zweifl. Insec. 1: 10.

Taeniorhynchus acer Walker. Theobald (1905: 106).

DISTRIBUTION: Dutch New Guinea: Fakfak, Manokwari (Brug and Haga, 1923; Bonne-Wepster, 1938); Assike, Merauke, Tanahmerah (Bonne-Wepster, 1938); Hollandia (Toffaleti and King, 1947); Padaido Islands (Author). Northeast New Guinea: Madang (Theobald, 1905; Hill, 1925); Bogadjim, Mount Hansemann, Yomo (Theobald, 1905); Lakekamu Gold Field (Breinl, 1915). Papua: Port Moresby (Taylor, 1914*a*; Hill, 1925); Yule Island, Samarai (Hill, 1925).

HABITAT: Bonne-Wepster and Brug (1937, 1939), Taylor (1943), and Lee (1944*a*) record *fatigans* from a variety of domestic habitats, and emphasize its occurrence in polluted water. I have a single, pure collection from the Padaido Islands, taken from a shaded well in stagnant water without vegetation.

Culex (Culex) sitiens Wiedemann

Culex sitiens Wiedemann, 1828, Aussereur. Zweifl. Insec. 1: 543.

Culicelsa annulirostris Skuse var. *milni* Taylor (1914*a*: 196).

Culex sitiens var. *milni* Taylor. Breinl (1915: 317).

Culex sitiens Edw. Brug and Haga (1923: 640).

Culex (*Culex*) *?sitiens* Wied. Brug (1934: 514).

DISTRIBUTION: Dutch New Guinea: Albatrosbivak (Brug, 1927; Bonne-Wepster, 1938); Pionierbivak (Brug and Haga, 1923; Bonne-Wepster, 1938); Sorong (Brug, 1934; Bonne-Wepster, 1938); Fakfak, Merauke, Tanahmerah, Toerai, Wamal (Bonne-Wepster, 1938); Hollandia (Toffaleti and King, 1947); Padaido Islands, Amsterdam Island (Author). Northeast New Guinea: Madang (Hill, 1925); Lakekamu Gold Field (Breinl, 1915); Finschhafen (Author). Papua: Milne Bay (Taylor, 1914*a*; Author); Yule Island, Samarai, Mekeo District, Moresby District (Hill, 1925).

HABITAT:

Total collections, 123

Habitat	*Number of collections*	*Habitat index*
Coral pools	115	93
Brackish puddles	4	3
Fallen trees on beach	2	2
Ditch	1	1
Artificial container	1	1

*p*H, 117 readings
Mode 7.0
Average 7.0

Factor	*Percentage occurrence*
Exposed	100
Temporary	5
Semi-permanent	95
Clear	88
Muddy	2
Murky	10
Vegetation	
Absent	36
Present	64
Algae	99
Emergent	1
Salinity	
Percentage sea water	
0– 18	66
18– 37	7
37– 55	6
55– 74	5
74– 93	9
93–100	6

Sitiens is apparently widely distributed along the north coast of New Guinea. However, it was common only at Amsterdam Island where 117 collections were obtained. The literature (Hill, 1925; Bonne-Wepster and Brug, 1937, 1939; Taylor, 1943; Lee, 1944*a*) gives a much wider variety of habitats than we have observed, often assigning equal importance to fresh and brackish water. In my collections the association with brackish water was absolute. But, for the most part, it was found in salinities ranging from 0 to 18 per cent sea water. It was found only along the beach in situations fully exposed to sunlight and subjected to salt spray or to storm tides. It occurred almost entirely (98 per cent) in pure collections. Its only associate was *An. farauti*.

Culex (Culex) squamosus (Taylor)

Culicada squamosa Taylor, 1914, Ent. Soc. London, Trans. 1913 (Part IV): 691.

Trichopronomyia annulata Theobald (1905: 98).

DISTRIBUTION: Dutch New Guinea: Upper Digoel River (Brug, 1934); Merauke (Bonne-Wepster, 1938); Padaido Islands (Author). Northeast New Guinea: Madang (Theobald, 1905; Edwards, 1924); Finschhafen (Author). Papua: Milne Bay (Lee, 1944*a*; Author).

HABITAT:

Total collections, 49

Habitat	*Number of collections*	*Habitat index*
Puddles	22	45
Creeks: Running	17	35
Creeks: Pot holes	7	14
Ditches	2	4
Ponds	1	2

*p*H, 9 readings

Range	5.0–7.0
Mode	5.0, 5.5
Average	5.7

Factor	*Percentage occurrence*
Shaded	11
Exposed	89
Temporary	45
Semi-permanent	18
Permanent	37
Clear	76
Muddy	9
Stagnant	15
Vegetation	
Absent	15
Present	85
Sparse	27
Moderate	35
Abundant	38
Algae	61
Emergent	11
Overhanging	2
Submerged	11
Floating	15

Squamosus was recorded from surface water only. It had a high affinity for the more permanent puddles and for creeks. The most striking habitat factor was vegetation, which was present in 85 per cent of the collections and was typically dense masses of algae flourishing in full sunlight. Hill (1925), Brug (1934), and Lee (1944*a*) also list surface water habitats but they apparently did not observe any striking abundance and frequency of vegetation in association with *squamosus.*

Squamosus occurred to approximately the same degree in pure (43 per cent) and in mixed (57 per cent) collections. Percentages of associates were: *An. farauti*, 18; *C. pullus*, 16; *An. punctulatus*, 12; *C. halifaxi*, 6; others, 5.

SUMMARY

Distribution

Edwards (1924) included 145 species from the Australasian Region and recorded 47 from New Guinea. Bonne-Wepster (1938) listed 121 non-anopheline species from the island. In 1944 Knight *et al.* listed 238 species from the Australasian Region and recorded 124 from New Guinea. I have specific locality records for 47 species. I believe that this discrepancy is due primarily to the fact that I engaged in routine surveys of each area rather than in intensive searching for species in unusual and inaccessible habitats.

In this paper many species are reported for the first time from major subdivisions of New Guinea. First records from Papua are presented for *U. argyrotarsis*, *A. candidoscutellum*, *A. dasyorrhus*, *C. brevipalpis*, *C. fraudatrix*, and *C. annulirostris.* First Northeast New Guinea records are presented for *U. argyrotarsis*, *U. papua*, *A. vexans*, *C. halifaxi*, *C. fragilis*, and *H. genurostris.* The collections of *A. aurantius chrysogaster* from Morobe and Milne Bay are apparently the first New Guinea records of the subspecies.

In assembling the records it became clear that frequently, in past surveys, novelties were recorded to the almost complete neglect of certain common species. Thus *Culex pullus*, one of the species most frequently encountered in my collections and present in every area studied, is represented in the literature by only two records from Northeast New Guinea and by a single one from Papua.

Table 1 summarizes distribution records from the study areas. The following generalizations may be given.

TABLE 1

Species Recorded from the Detail Study Areas

SPECIES	MILNE BAY	MOROBE	FINSCH-HAFEN	SAIDOR	PADAIDO	AMSTER-DAM
B. soesiloi	x					
B. travestitus	x					
An. b. pseudobarbirostris				x		
An. farauti	x		x	x	x	x
An. longirostris	x					
An. punctulatus	x		x	x	x	
Toxorhynchites spp.	x		x	x	x	
T. confusa	x					
T. argenteiventris	x		x			
T. bimaculipes	x					x
T. brevipalpis?			x		x	
H. genurostris				x		
U. albescens	x					
U. argyrotarsis	x		x	x		
U. nigerrima	x		x	x	x	
U. papua	x		x	x	x	
A. a. chrysogaster	x	x			x	
A. candidoscutellum	x					
A. hollandius	x					
A. keefei	x					
A. kochi	x			x		x
A. notoscriptus	x		x	x	x	x
A. novalbitarsis	x				x	
A. papuensis	x	x	x		x	
A. wallacei	x					
A. dasyorrhus	x					
A. albolineatus	x	x	x	x	x	x
A. scutellaris	x	x	x	x	x	x
A. vexans	x		x	x		
A. funereus	x		x	x		
A. lineatus	x		x	x		
A. parasimilis	x	x	x		x	
A. aurimargo			x			
Arm. breinli	x	x	x		x	
Arm. milnensis	x	x				
C. halifaxi	x	x	x	x	x	
C. brevipalpis	x					
C. fraudatrix	x		x	x		
C. ?uniformis					x	
C. fragilis	x		x	x	x	
C. papuensis	x		x			
C. pullus	x	x	x	x	x	
C. bicki	x					
C. annulirostris	x			x	x	x
C. fatigans					x	
C. sitiens	x		x		x	x
C. squamosus	x		x		x	

1. Nearly all of the 47 species recorded were found at Milne Bay. A significant number of species found at Milne Bay dropped from the list only at Amsterdam Island. The apparent spotty distribution of certain species is thought to be due largely to habitat availability at the particular locality rather than to distinct range limitations.

2. A distance of approximately 1,300 miles separates Milne Bay from Padaido and Amsterdam Islands, yet the latter localities added only *C. fatigans*, *C. ?uniformis*, and *T. brevi-*

palpis? to the list for Milne Bay.

3. Four species of Anopheles (*farauti*, *punctulatus*, *bancrofti pseudobarbirostris*, *longirostris*) are recorded. *Bancrofti* and *longirostris* were rare; the former was found only at Saidor and the latter only at Milne Bay. *Farauti* and *punctulatus* were common to extremely abundant in nearly every area. Because of their abundance and widespread distribution it seems that only these could be significant malaria vectors in New Guinea.

4. *Aedes scutellaris* was the only species common in every locality. Because of its abundance and widespread distribution, and considering the results of transmission experiments, this species is of considerably greater significance as a dengue vector than all other culicines.

5. *Aedes albopictus*, so frequently reported as common, was not recorded. *Culex fatigans* was found only in a single collection from the Padaido Islands. *Aedes aegypti* was represented by a single adult collection from Samarai Island.

6. Based on distribution and numerical abundance, *C. pullus*, *C. halifaxi*, *A. albolineatus*, and *A. notoscriptus* are potentially important pest species along the north coast. However, practically nothing on their biting habits has been recorded. In particular areas other species may assume local importance, as *Armigeres milnensis*, which was exceptionally abundant at Milne Bay, and *Culex sitiens* at Amsterdam Island.

Habitats

Table 2 lists the number of collections from

TABLE 2
COLLECTION SUMMARY ACCORDING TO HABITAT AND LOCALITY

	MILNE BAY	MOROBE	FINSCH-HAFEN	SAIDOR	PADAIDO ISLAND	AMSTER-DAM ISLAND	TOTAL	PER CENT
Fresh Surface Water								
Natural								
Creeks: Running.....(P)*	57		1	1			59	3.9
Creeks: Pot holes.....(S)	91		2				93	6.1
Swamps.............(P)	23	2		12			37	2.5
Ponds..............(P)	5			5			10	0.7
Marshes............(P)	4					12	16	1.1
Artificial								
Puddles............(T)	320	1	4	28	14	7	374	24.8
Borrow pits..........(S)	18		1	2			21	1.3
Ditches.............(S)	29			1			30	2.0
Wells...............(P)				1	2		3	0.2
Fresh Water in Containers								
Natural								
Shells...............(T)					1		1	0.1
Rock holes..........(T)	34						34	2.2
Leaf axils............(T)	50			9		5	64	4.2
Spathes and leaves....(T)	9		2	1	5	5	22	1.4
Tree holes...........(T)	76		3	8	20	12	119	7.9
Coconut shells.......(T)	75		4	8	39	48	174	11.6
Artificial.............(T)	241		17	20	43	4	325	21.6
Brackish Water								
Coral pools..........(S)						117	117	7.8
Puddles.............(T)	2						2	0.1
Tree holes...........(T)	5					2	7	0.2
Total collections...............	1,039	3	34	96	124	212	1,508	100.0

*P = Permanent, S = Semi-permanent, T = Temporary.

TABLE 3

Species-Habitat Summary of Species Represented by More than 10 Collections. Figures are Habitat Indices; Those Less than 10 Are Excluded. Solid Lines Separate Surface Habitats from Container Habitats and Surface Species from Container Species. Dotted Lines Separate Natural and Artificial Habitats

	RUNNING CREEKS	CREEK POT HOLES	SWAMPS	PUDDLES	ROCK HOLES	LEAF AXILS	SPATHES AND LEAVES	TREE HOLES	COCONUTS	ARTIFICIAL CONTAINERS	OTHERS
Surface water											
Natural											
Bironella spp.	41	56									3
U. argyrotarsis		41	15	15							28
C. fraudatrix		24	24	16							36
C. squamosus	35	14		45							6
Artificial											
An. farauti	15	13		52							20
C. pullus		11		62						13	13
C. halifaxi		12		64						14	9
C. annulirostris				75							25
An. punctulatus				83							17
A. vexans				92							8
C. papuensis		17		24						39	19
A. novalbitarsis				42	50						8
A. papuensis				26	38					15	21
Water in containers											
Natural											
A. kochi						100					0
A. keefei								91			9
Arm. breinli									94		6
Natural and artificial											
U. papua							33		12	38	16
U. nigerrima							14		29	53	4
A. albolineatus								52	25	15	7
A. notoscriptus								51	13	34	2
Arm. milnensis								18	50	24	8
Toxorhynchites spp.								15	15	68	2
T. bimaculipes								13	13	68	5
A. scutellaris								11	32	45	11
C. fragilis									11	62	26

each of the habitats by locality. It will be noted that:

1. Nearly every habitat was represented at Milne Bay. This locality was the most productive in both species and numbers of individuals. However, since the collection period here was much longer, strict comparison with the other areas is not warranted.

2. Morobe was markedly unproductive largely because natural barriers sharply limited the study area. A light rainfall during the brief collecting period further reduced collection possibilities.

3. Collections from "fresh water in containers" were well represented at nearly every locality, whereas, with the exception of the

ubiquitous puddles, collections from "fresh surface water" had a more scattered distribution. This was directly correlated with the availability of these habitats.

4. Ninety-two per cent of all collections were from fresh water, only 8 per cent from brackish. All brackish habitats were temporary or semi-permanent and were sharply localized. This was due largely to the scarcity and total non-productivity of brackish marshes and swamps. In several areas (especially Gamadodo and Morobe) extensive mangrove swamps were present but mosquito larvae were entirely absent, probably due to a significant daily tidal fluctuation.

5. Seventy-five per cent of the collections were from temporary water, 17 per cent from semi-permanent, and only 8 per cent were from permanent water. Since there was a remarkably high percentage of collections from temporary water, I believe that a significant degree of control could have been achieved by dealing solely with these habitats.

6. Approximately 50 per cent of all collections were from puddles and artificial containers. This figure emphasizes the overwhelming importance of man-made habitats.

Table 3 gives the habitat indices for each fresh-water species represented by more than 10 collections. In each case only habitats with indices greater than 10 are included. It is felt that lower figures represent habitats too rarely utilized to be significant.

The habitats are arranged in a sequence from clear, natural surface water to polluted water in artificial containers. Within this sequence they fall into three major categories, each with its characteristic group of species.

1. In clear, natural surface water, characteristic species were *Bironella* spp., *U. argyrotarsis*, and *C. fraudatrix*.

2. Artificial surface water was almost entirely puddles. Characteristic species were: *An. farauti*, *C. pullus*, *C. halifaxi*, *An. punctulatus*, *A. vexans*, and *C. annulirostris*.

3. In water in containers, characteristic species were: (a) *A. kochi*, *A. keefei*, and *Arm. breinli*, which were found primarily in natural containers; and (b) *U. papua*, *U. nigerrima*, *A. albolineatus*, *A. notoscriptus*, *Arm. milnensis*, *Toxorhynchites* spp., *T. bimaculipes*, *A. scutellaris*, and *C. fragilis*, which were found in both natural and artificial containers.

Very few species bridge the gap between surface and container habitats to a significant degree. Only *C. papuensis*, *A. novalbitarsis*, and *A. papuensis* were frequent in both surface water and in water in containers.

Of the disease vectors, *An. farauti* and *An. punctulatus* occurred primarily in artificial surface water habitats whereas *A. scutellaris* was found primarily in containers.

Habitat Factors

Exposure: In most cases shade or exposure was a natural characteristic of the habitat. For example, tree holes and mountain creeks, by their nature, are shaded, whereas coral pools are exposed. Species with high indices for such habitats showed correspondingly high values for shade or for exposure. In these cases the actual role of this factor could not be determined. However, for several species, exposure seemed significant. *An. punctulatus* and *A. vexans* were common in exposed puddles, whereas *C. annulirostris* was more frequent in shaded puddles. *A. albolineatus* and *C. fraudatrix* were found in a wide habitat range but typically in shaded situations.

Superficial character of water: Based on organoleptic methods, the habitats were divided into four categories: clear, muddy, stagnant, polluted. For the most part, a particular species was not found solely in any one of these categories. This would be expected because of the wide habitat range for nearly every species. However, the following were frequently associated with these water types: Clear—*Bironella* spp., *H. genurostris*, *A. keefei*, and *A. dasyorrhus;* muddy—*An. punctulatus*, *C. halifaxi*, and *C. pullus*; polluted—*Arm. breinli*, *Arm. milnensis*, and *C. fragilis*.

TABLE 4

Association Per Cent of the Various Species. Species Represented by Less than 10 Collections are Excluded and All Association Values Less than Four Have Been Added and Lumped under "Others." Read Numbers Horizontally

	Bironella spp.	*U. argyrotarsis*	*C. fraudatrix*	*C. squamosus*	*An. farauti*	*C. pullus*	*C. halifaxi*	*C. annulirostris*	*An. punctulatus*	*A. vexans*	*C. papuensis*	*A. novalbitarsis*	*A. papuensis*	*A. kochi*	*A. keefei*	*Arm. breinli*	*U. papua*	*U. nigerrima*	*A. albolineatus*	*A. notoscriptus*	*Arm. milnensis*	*Toxorhynchites* spp.	*T. bimaculipes*	*A. scutellaris*	*C. fragilis*	Others
Bironella spp.	68	11	9			4																				8
U. argyrotarsis	5	29	7		10	20	13																			16
C. fraudatrix	7	17	16		26		4	6	7																	17
C. squamosus				43	18	16	6		12																	5
An. farauti		4	5	8	23	21	11	6	16																	6
C. pullus		6		4	15	24	17	4	13		4															13
C. halifaxi		6			11	25	18	6	14		5															15
C. annulirostris					16	16	13	26	16																	13
An. punctulatus				5	15	18	12	6	35																	9
A. vexans						17			25	25																33
C. papuensis		5			5	27	21		5		26															11
A. novalbitarsis												67														33
A. papuensis						8	8		6				36						8			5				29
A. kochi														86												14
A. keefei															36				14			14	8	14		14
Arm. breinli																86		4								10
U. papua																	71		4					5		20
U. nigerrima																9		52	7			6	9	6	6	5
A. albolineatus													5					4	44	6		4	7	11	4	15
A. notoscriptus																5			9	60			5		5	16
Arm. milnensis																					84					16
Toxorhynchites spp.																5			5			52	5	6	5	22
T. bimaculipes		5																11	19	7	5	7	16	14		16
A. scutellaris																			6					73		21
C. fragilis						12	10											4	7	5		4		10	37	11

Vegetation: For most species vegetation was a minor factor since it was entirely absent in 41 per cent of the collections. This is not surprising in view of the temporary nature of so many of the habitats. There was a striking correlation between the type of vegetation and a particular species in only one case: *C. squamosus* was found with vegetation in 85 per cent of the collections and, of these, 61 per cent were with green algae.

*p*H: Nearly every species was found within a wide range. Alkaline readings were relatively few, and for no species was the mode or average alkaline. In general, there was little or no correlation between any one species and certain narrow *p*H values.

Species Association

In Table 4 the species represented by less than 10 collections are excluded and all association values less than four are added and lumped under "others."

Conclusions from this table substantiate those of the habitat table. That is, surface water species have high association values for one another, and, likewise, container species have high association values for one another. The separation of surface water species and container species is quite apparent.

However, as with the habitat groups, there is overlapping. The following, which were found both in surface and container habitats, are likewise found with both surface and container associates: *C. papuensis*, *A. novalbitarsis*, and *A. papuensis*. These three are clearly in an intermediate position.

For almost every species the number of pure collections exceeded the number of associations with any other particular species. *A. kochi*, *Arm. milnensis*, and *Arm. breinli* had the highest values for pure collections.

It is usually stated that predatory species are found more commonly in pure collections. My figures were not unusually high for the predatory species, *Toxorhynchites* spp. and *Culex halifaxi*. Indeed, in the case of *halifaxi*, the value 18 was surprisingly low.

The association of a particular species with any one other exceeded 20 in very few cases. It is believed that the concept of indicator species is in no case substantiated by these data. Examples of the highest associations were: *C. papuensis* with *C. pullus* (27), *C. fraudatrix* with *An. farauti* (26), *C. halifaxi* with *C. pullus* (25), and *A. vexans* with *An. punctulatus* (25).

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News Notes

Dr. Joshua T. Tracey, Jr., Geologic Division, U. S. Geological Survey, has been designated chief of a field party which is undertaking a detailed geological survey of Guam, as a part of the Pacific Geologic Surveys program of the Military Geology Branch. He will be assisted by David B. Doan and Harold G. May.

Simultaneously, Joseph W. Brookhart, Theodore Arnow, and Raymond Chum, of the Water Resources Division, U. S. Geological Survey, are conducting a comprehensive survey of the island's water resources.

To review the existing research and control programs for filariasis and elephantiasis, and to propose further measures for combating them, a conference of medical experts was held in Papeete from August 21 to September 1, 1951. The first international gathering of its kind, it was organized by the South Pacific Commission as part of its program to promote the physical, economic, and social welfare of island peoples in the South Pacific. Nineteen specialists attended, representing Australia, England, New Zealand, Samoa, Tahiti, United States, and Vietnam. Also attending were observers from medical and other institutions in Tahiti.

The three main objectives of the conference were: To define the various problems raised by filariasis and elephantiasis; to determine the research work to be continued or undertaken to solve these problems; and to recommend appropriate measures for the control of these diseases, with special reference to the social and economic conditions of the area.

The conference was opened by His Excellency the Governor of French Oceania, M. Petitbon. Dr. Emil Massal, Executive Officer for Health of the South Pacific Commission, was elected chairman of the conference.

The conference proposed the following recommendations:

The South Pacific Commission should act as a focal point for the area in the collection, collation, and dissemination of technical data relating to these diseases.

Techniques now in use for controlling filariae-carrying mosquitoes should be reviewed and their wider application considered, using specially trained native personnel.

Research now being conducted in Tahiti, Samoa, and Fiji on the control of these diseases by drugs should be continued and intensified.

The Commission should establish a filariae collection of specimens of larvae and adult worms and of microfilariae in human blood samples, arrange for study of this material by parasitologists, and circulate the findings throughout the area.

Detailed recommendations regarding the collection, preservation, and identification of specimens and laboratory diagnosis for microfilariae should be brought to the attention of member governments, territorial administrations, and all private institutions and individuals interested in the problem.

The Commission should act as a clearing house for posters, pamphlets, and other educational material for use in the intensified campaign against these diesases.

The findings of the conference will be considered at the Eighth Session of the South Pacific Commission, which will open at Commission headquarters in Noumea, New Caledonia, during the last week in October.

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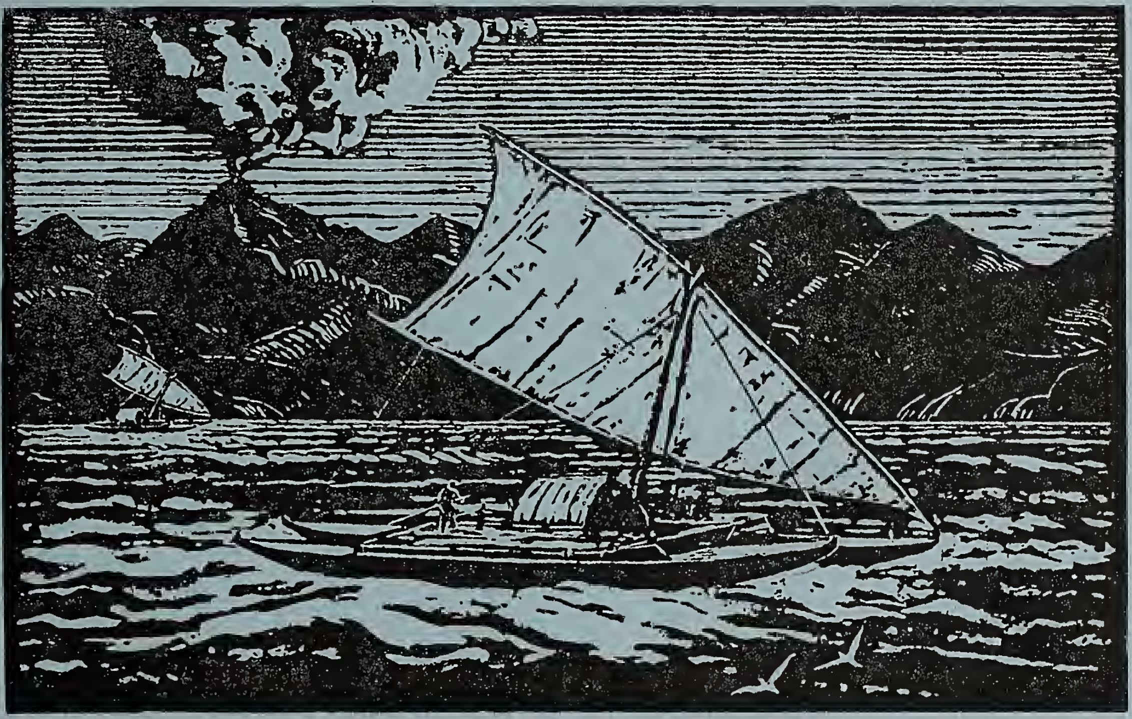

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Notes on a Collection of Orchids from Ponape, Caroline Islands[1]

ALEX D. HAWKES[2]

THE CAROLINE ISLANDS of the Micronesian area of the Pacific, which extend in an approximately east-west direction for some 1,950 miles, between about 5° and 10° north latitude, are almost directly north of New Guinea, the Bismarck Archipelago, and the Solomon Islands, the center of distribution for the family Orchidaceae. It is, therefore, to be anticipated that the orchid flora of the Carolines is fairly extensive; such is indeed the case, though our knowledge of the flora of the area is still somewhat incomplete. The novelties incorporated in the present paper indicate that further exploration in the Carolines will doubtless increase the numbers known in the orchidaceous flora of the islands.

The present interesting collection of Orchidaceae from Ponape was assembled by Philip A. Adams, while engaged in entomological surveys of the island.[3] The materials, consisting of both herbarium and living specimens, were sent to the Botanical Garden of the University of California at Berkeley at the instigation of Dr. T. Harper Goodspeed. The writer must thank him for permission to study the collection, and for reading and checking the paper in its final stages. His further thanks go to Dr. Lincoln Constance for assistance in taxonomic problems and for supervising the work in progress; and to Dr. Rimo Bacigalupi for assistance with the Latin diagnoses.

BULBOPHYLLUM Thouars

Orch. Îles Afr., Tabl. des Espèc. 3, et Icon., tt. 93–97, 1822.

Eight or nine species of this gigantic and highly complex genus are now known from the Carolines. The group would greatly profit by critical revision in the area.

Bulbophyllum Gibbonianum Schltr., Engl. Bot. Jahrb. 56: 483, 1920. (§ *Scyphosepalum*)

Mt. Sankaku, 1,100 ft. alt.: this species grows on tree trunks, fallen logs, mossy rocks and soil. Especially healthy plants were on rotten logs and bases of Bird's Nest Ferns (*Asplenium nidus* L.). The flower is eggplant purple. The species was seen nowhere but on the summit of Mt. Sankaku. August, 1950, *P. A. Adams 24*.

This attractive dwarf epiphyte was originally described from specimens collected by C. Ledermann on the island of Babelthuap in the Palau group. Our plant is rather larger in all parts than the type material, and differs in floral color, the blossoms as described by Schlechter being noted as "rotbraun, mit braungelber Lippe." It has not been reported previously from Ponape. The only other species of the section *Scyphosepalum* is the New Guinean *B. nuruanum* Schltr. Living material is in cultivation at the Botanical Garden of the University of California at Berkeley.

Bulbophyllum micronesiacum Schltr., Engl. Bot. Jahrb. 56: 482, 1920. (§ *Dialeipanthe*)

Mt. Beirut, 2,200 ft. alt.: epiphytic, common in primary forest from about 1,500 ft.

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[1] Contribution No. 122 from the Botanical Garden of the University of California.

[2] Department of Botany, University of California, Berkeley. Manuscript received February 13, 1951.

[3] These studies were aided by a contract between the Office of Naval Research, Department of the Navy, and the National Academy of Sciences (NR161-472).

Petals greenish white, pink at bases. Spur of chin deep red. August, 1950, *P. A. Adams 16;* Mt. Kubersoh, 2,000 ft. alt.: on base of Bird's Nest Fern. August, 1950, *P. A. Adams 22.*

Bulbophyllum micronesiacum Schltr. is also known from Yap and Rota, and from Babelthuap in the Palaus. It is a very distinctive and handsome large-flowered species allied to *B. guamense* Ames from the Marianas. Living material is in cultivation at the Botanical Garden of the University of California at Berkeley.

Bulbophyllum urceolatum A. D. Hawkes, sp. nov. (Fig. 1)

Herba epiphytica nana repens. Rhizoma repens, cylindricum. Pseudobulbi ascendentes arcuati semi-erective, ovoidei usque ad cylindrico-ovoidei, leviter angulati, diphylli. Folia 2, id interiorum insigniter parvius ac minus evolutum, erecta arcuatave, coriacea, ovato-lanceolata usque ad oblongo-lanceolata, plus minusve carinate apiculata vel oblique bilobata, basi angustiora conduplicataque. Inflorescentia verisimiliter terminalis, erecto-arcuata, uniflora; rachis leviter angularis. Flores solitarii, erecto-arcuati, urceolati, coriacei. Sepala basi coherentia apice ecurvata, triangulari-lanceolata triangulari-ovatave, acuta, marginibus patrium liberarum leviter introrsis; lateralia basi mentum rotundo-truncatum formantia, prominente carinata. Petala sepalis aequilonga, lineari-lanceolata, infra medium abrupte expansa, acuta, apice ecurvata, basi truncata. Labellum semi-transparens, textura tenuissima, immotum, expansum obovatum, basi unguiculatum, subacutum, ecallosum, prope basin saccum truncatum formans, margine laterali leviter incurva, disco lineas irregulares longitudinales aliquanto impressas ferente.

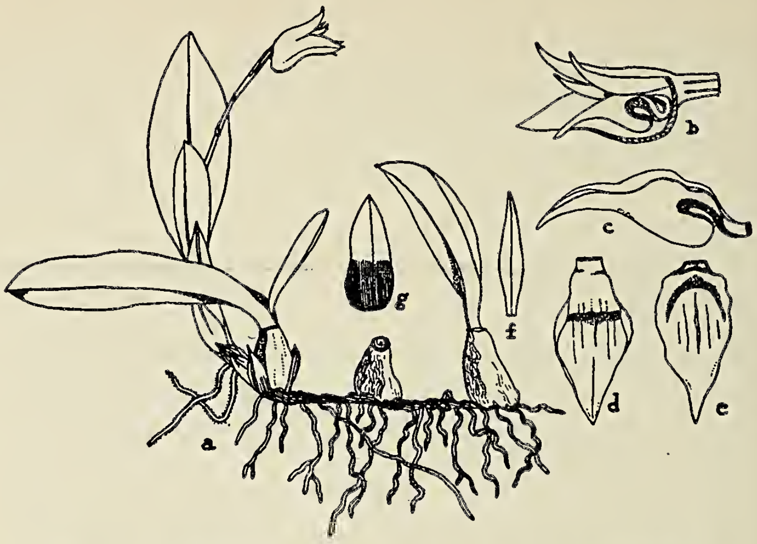

FIG. 1. *Bulbophyllum urceolatum* A. D. Hawkes, sp. nov. *a*, Habit, ×1; *b*, flower, lateral view, one lateral sepal removed, ×2.5; *c*, labellum, lateral view, ×5; *d*, labellum, dorsal view, ×4; *e*, labellum, ventral view, ×4; *f*, petal, ×5; *g*, lateral sepal, ×2.5.

Dwarf creeping epiphytic herb. Rhizome repent, 2–3 mm. in diameter, more or less covered with somewhat leathery, brown sheaths, giving off pseudobulbs at intervals, mostly cylindrical. Roots filiform, flexuose, brown or reddish-maroon, distinctly villous when young, later glabrous. Pseudobulbs produced at intervals, 2–12 mm. apart, ascending, somewhat arcuate or semi-erect, ovoid to cylindrical-ovoid, often vaguely angular (especially when young), wrinkled when old, 12–15 mm. long, 6–8 mm. in diameter near base, narrowing above, diphyllous; basal sheaths usually geminate, caducous, scarious, triangular-lanceolate, acuminate, about 1 cm. long and about 8 mm. broad basally. Leaves 2 (one often caducous), the inner one much smaller and less developed, erect or arcuate, leathery, light green, ovate-lanceolate to oblong-lanceolate, more or less carinately apiculate to obliquely bilobate, narrowed and conduplicate basally, 4–7.5 cm. long, 8.5–16 mm. broad at widest point; secondary leaf less coriaceous in texture, carinately apiculate, rather conduplicate, oblong-lanceolate to ovate-lanceolate, about 2.5–3 cm. long, about 5–7.5 mm. broad. Inflorescence apparently terminal, erect-arcuate, 1-flowered, to about 4 cm. long; rachis vaguely angular, about 1 mm. in diameter, tinged with vermilion above the bract, green below; bract solitary, clasping basally, submembranaceous, triangular-lanceolate, long-acute, about 2 mm. long. Flower solitary, erect-arcuate, urceolate, coriaceous, the sepals and petals flaring somewhat in apical half, odorless, 11 mm. long, about 5 mm. broad, basal half vermilion, apical half canary yellow. Sepals similar, thick, coherent for about half of length (the laterals slightly more), flaring apically, triangular-lanceolate or ovate-triangular, acute, the margins of the free portion slightly introrse, about 10.5×3 mm.; laterals at base forming a rotund-truncate mentum about 3 mm. long, rather prominently carinate. Petals almost as long as sepals, about 1 mm. wide, linear-lanceolate, with a slight, rather abrupt expansion just below the middle, acute, the apex curved outward, truncate basally. Labellum very thin in texture, almost transparent, 8×3 mm., non-mobile, entire, obovate when expanded, unguiculate basally, acutish, expanded into a rather truncate sac near base which projects half-way under the unguicule, ecallose, with irregular, somewhat impressed longitudinal lines along the disc, lateral margins somewhat incurved.

Mt. Beirut, 2,200 ft. alt.: on trees with #9 (*Bulbophyllum* sp.). Flowers of this species not seen, but I am told that they are pale orange with green-tipped petals, arising singly from the tips of the pseudobulbs. August, 1950, *P.A. Adams 10*, TYPE, flowering under cultivation at the Botanical Garden of the University of California, and deposited as a pickled specimen in the Herbarium of this institution.

This handsome little epiphyte is not allied to any species of *Bulbophyllum* known to the writer. Its labellar structure, coupled with the unique conformation of the flowers, appears unique in the genus.

Bulbophyllum sp.

Mt. Beirut, 2,200 ft. alt.: on dwarf trees with #10 (*Bulbophyllum* sp.), #7 (*Diplocaulobium carolinense* A. D. Hawkes), #5 (*Dendrobium nanarauticolum* Fukuyama), #16 (*Bulbophyllum micronesiacum* Schltr.). Flower not seen. August, 1950, *P. A. Adams 9*. A sterile specimen, with living material in our collections.

DENDROBIUM Swartz

Soc. Sci. Uppsala, Nova Act. 6: 82, 1799.

This is the largest genus in the Caroline orchid flora, with 15 or 16 species now known from the area.

Dendrobium Adamsii A. D. Hawkes, sp. nov. (§ *Grastidium*)

Herba epiphytica verisimiliter elongata. Caulis (in specimina mihi visa imperfectus) 12 cm. longus, 2.5–3.5 mm. latus, leviter arcuatus, luteus, vaginis foliorum arcte obtectus, complanatus. Folia numerosa, coriacea, 5–5.5 cm. longa, usque ad 8–10 mm. lata, oblongo-lanceolata, apicibus angustioribus ensiformi-linearibus, emarginatus vel oblique bilobatis, basi obscure conduplicata. Pedunculi abbreviati, ca. 3 mm. longi, bracteis paucis obtusis obtecti. Flores solitarii vel 2-ni, membranacei, 1.5 cm. longi, campanulati. Sepala lineari-lanceolata, 12 mm. longa, 1.5 mm. lata, acuta, lateralia margine anteriore basi dilatata cum pede columnae mentum triangulum vel rotundo-triangulum obtusumque formantia. Petala sepalis lateralibus similaria lineari-lanceolata, apice obtusa. Labellum parvum, trilobatum, apice recurvatum; lobis lateralibus erectis, triangularis, margine anteriore dentatis; lobo intermedio cuneato-oblongo, papilloso, apice acuminato quasi caudato. Columna brevis, quasi quadrata.

Epiphytic herb, in our specimen incomplete, apparently rather elongate. Stem (incomplete) 12 cm. long, 2.5–3.5 mm. thick, rather arcuate, yellowish, vaguely zigzag, virtually covered by persistent sheathing leaf bases, complanate, the leaf bases mostly about 1.5 cm. long, obscurely articulate. Leaves numerous, rather coriaceous, 5–5.5 cm. long, 8–10 mm. wide at broadest point, oblong-lanceolate, narrowing rather abruptly toward the much narrower ensiform-linear apical portion, which is deeply emarginate or obliquely bilobate, basally somewhat conduplicate. Peduncles abbreviated, about 3 mm. long, almost as broad, covered with a few obtuse bracts. Flowers solitary or paired, rather membranaceous when dry, "pale green, petals pinkish inside, labellum with purplish-red median mark inside, very fragrant, wilt after about 6 hours" [*fide* collector], 1.5 cm. long, campanulate, borne on vaguely arcuate rather robust pedicellate ovaries about 8 mm. long. Dorsal sepal linear-lanceolate, acute, 12 mm. long and 1.5 mm. broad. Lateral sepals oblique, basally connate into a large, angular, compressed mentum that is triangular-rotund and obtuse in shape, about 6 mm. long and 3 mm. deep; lamina linear-ligulate or ovate-ligulate, truncate or obtuse, about 12 mm. long and 1 mm. wide. Petals similar in size and shape to lateral sepals but more lanceolate basally, obtuse apically. Lip small, the tip recurved, about 5 mm. long and 1.5 mm. broad, prominently trilobate; lateral lobes erect, triangular, forward-slanting, the anterior margin strongly dentate; midlobe cuneate-oblong, covered with a dense growth of apiculate papillae, the apex acuminate and almost caudate. Column 0.5 mm. long, almost as wide, semiquadrate; foot large.

Mt. Kubersoh, 2,000 ft. alt.: on mossy tree trunks, flowers pale green, petals pinkish inside, labellum with purplish-red median mark inside; blooms very fragrant, wilt after about 6 hours. August, 1950, *P. A. Adams 19*, TYPE, deposited in the Herbarium of the University of California at Berkeley (916873).

This is a rather handsome species of § *Grastidium*, whose closest alliance in the Caroline orchid flora is with *Dendrobium implicatum* Fukuyama, *D. patenti-filiforme* Hosokawa, and *D. ponapense* Schltr.; it also exhibits some affinity with the Moluccan *D. pruinosum* Teijsm. & Binn. It differs from *D. implicatum*, its nearest relative, in its more plane lateral sepals, the dimensions of the mentum, the size and general aspect of the flowers, and the more robust vegetative habit. Living material of the novelty, which I take pleasure in naming for its collector, is in cultivation in the Botanical Garden of the University of California at Berkeley.

Dendrobium carolinense Schltr., Engl. Bot. Jahrb. 56: 472, 1920. (§ *Grastidium*)

Mt. Kubersoh, 1,200 ft. alt.: on dead tree trunk with Bird's Nest Fern. Flowers pale golden yellow with bright orange median mark on inside of white labellum. August, 1950, *P. A. Adams 18*. A very handsome epiphyte, known now from Kusaie, Truk, and Ponape, where it appears to be rather widespread in its occurrence.

Dendrobium implicatum Fukuyama, Bot. Mag. [Tokyo] 51: 901, fig. 2, 1937. (§ *Grastidium*)

Mt. Tolotom, 1,700 ft. alt.: on trunk of hardwood, flower pale pink with darker maculations, August, 1950, *P. A. Adams 3;* Mt. Tolenkiup, 1,700 ft. alt.: epiphyte, flower pale green. August, 1950, *P. A. Adams 13*.

The type specimen of *Dendrobium implicatum* Fukuyama was collected by T. Hosokawa in the Palau Islands, with the comment "in parinarietis." Our present material from Ponape is fragmentary, but the plants appear to be much smaller in all parts than the type (e.g., *Adams 13* has flowers which measure only about 2 cm. long, whereas the lateral sepals of *Hosokawa 7275* reach a length of 4–4.5 cm.). Living material is being grown in our collections.

Dendrobium nanarauticolum Fukuyama, Bot. Mag. [Tokyo] 51: 900, fig. 1, 1937. (§ *Oxyglossum*)

Mt. Tolotom, 2,100 ft. alt.: on mossy trees with #1 (*Dendrobium violaceo-miniatum* Schltr.) and #4 (*Geissanthera Hosokawae* (Fukuyama) A. D. Hawkes), also common on the summit of Mt. Beirut. August, 1950, *P. A. Adams 5;* Mt. Kubersoh, 2,000 ft. alt.: same sp. as #5, on mossy trees. August, 1950, *P. A. Adams 23*.

This is an attractive, very dwarfed epiphyte which at first inspection appears to be a species of *Bulbophyllum* Thou. The section *Oxyglossum* is predominantly New Guinean in distribution, with about 25 species native on that island; the present plant is apparently closest to *D. coerulescens* Schltr. The type specimen (*Hosokawa 6003*) was collected on the Ponapean Mt. Nanaraut (=Nanalaut) at an elevation of 680 meters.

Dendrobium ponapense Schltr., Engl. Bot. Jahrb. 56: 471, 1920. (§ *Grastidium*)

Mt. Sankaku, 1,100 ft. alt.: on tree trunks, hanging from Bird's Nest Ferns, etc. The older plants all had an accumulation of organic material in the roots; epiphytic; bloom white, inside of labellum violet with pale median orange stripe. The showiest *Dendrobium* encountered. August, 1950, *P. A. Adams 29.*

The type of this handsome epiphyte was collected by Ledermann on the island of Ponape, "ohne nähere Angaben." It is allied to the new *Dendrobium Adamsii* A. D. Hawkes (supra), *D. implicatum* Fukuyama and *D. pruinosum* Teijsm. & Binn. Our specimen, though incomplete, appears to match rather well the type description by Schlechter. Living material is in cultivation at the Botanical Garden of the University of California at Berkeley.

Dendrobium violaceo-miniatum Schltr., Engl. Bot. Jahrb. 56: 470, 1920. (§ *Oxyglossum*)

Mt. Tolotom, 2,100 ft. alt.: on trunk of *Hibiscus tiliaceus*, perianth blue, tip of lip brownish-orange; common throughout the primary forest from 1,300 ft. up; does best in open, sunny areas. August, 1950, *P. A. Adams 1;* Mt. Kubersoh, 2,000 ft. alt.: same sp. as #1, but flower white. August, 1950, *P. A. Adams 21.*

This, the second species of section *Oxyglossum* present in the collection, is a very handsome and unusual dwarf plant, reminiscent of a *Bulbophyllum* Thou. or *Eria* Ldl. in superficial vegetative habit. It is allied to *Dendrobium lapeyrousioides* Schltr. from Kaiser-Wilhelmsland, New Guinea. The type specimen (*C. Ledermann 13415*) was collected "in niedrigem Buschwald, bei Patapat (=Potopot), auf Ponape, 200 bis 300 m ü. M." Living material is in our collections at this time.

Dendrobium spp.

Mt. Beirut, 2,200 ft. alt.: epiphyte, flowers not seen. August, 1950, *P. A. Adams 12.* This sterile specimen, of which living material is in cultivation at the Botanical Garden of the University of California, is perhaps referable to *Dendrobium implicatum* Fukuyama.

Palakir: ½ mile south of Airfield No. 2, on hardwood, in deep shade. Flower not seen. August, 1950, *P. A. Adams 14.* Only an indeterminable sterile fragment is present.

Forty-five minutes up trail from Nanpil to Tolenkiup: on fallen tree with #8 (*Sarcanthinae*, sterile), epiphytic, same sp. as #14 (*Dendrobium* sp.). August, 1950, *P. A. Adams 15.* Living material of this orchid is in the Botanical Garden of the University of California.

Mt. Sankaku, 1,100 ft. alt.: on bare tree trunks, blooms not seen. August, 1950, *P. A. Adams 25.* Only an indeterminable sterile fragment is present. Living material is in our collections.

DIPLOCAULOBIUM (Reichenbach filius) Kraenzlin

In Engl., *Pflanzenr.* 4, 50, ii, B, 21: 331, 1910.

Three species of this very interesting dendrobioid genus are now known from the Carolines, one of which is apparently new.

Diplocaulobium carolinense A. D. Hawkes, sp. nov.

Herba parva epiphytica, caespitosa. Rhizoma breve, repens, cataphyllis obtecta. Pseudobulbi erecti, in sicco lutei, 6–13 cm. longi, basi 3–5 mm. lati, apice 2.5–3 mm. lati, basi ovoideo-attenuati, ad apicem versus elongatoligulati ancipitique, monophylli. Folium erectum, planum, coriaceum, ca. 6.5–8 cm. longum, 8–9.5 mm. latum, leviter undulatum, lineari-ligulatum usque ad oblongo-ligulatum, apice profunde emarginatum. Spatha ensiformis, scariosa, ca. 2 cm. longa, 2.5–3 mm. lata. Flores solitarii vel pauci, fugaces, ca. 4.5 cm. diametientes. Sepala lineari-lanceolata, longe-caudata, 5-nervosa, lateralia cum pede columnae mentum obtusum triangulum formantia. Petala filiformia, longe-caudata, basi paululum expansa. Labellum 9 mm. longum, 1.5–4.5 mm. latum, ad basim longe-unguiculatum; lobis lateralibus erectis, elongato-triangularis, obtusis truncatisve, nervosis; lobo intermedio magno, basi oblongo, apice patente, ellipsoideo, margine undulato crispatoque, obscure 3-lamellato papillosoque. Columna brevis, obtusa.

Small epiphyte in sunny places of primary forest, clustered. Rhizome abbreviated, repent, covered with sheathing scarious cataphylls. Pseudobulbs erect, yellowish when dry, 6–13 cm. long, 3–5 mm. thick basally, narrowing to 2.5–3 mm. apically, ovoid-attenuate basally, narrowing above to an ancipitous ligulate prolongation, at or near the apex of which the solitary leaf and large floral sheath are produced. Leaf erect, plane, coriaceous, about 6.5–8 cm. long, 8–9.5 mm. wide, vaguely undulate, linear-ligulate to oblong-ligulate, distinctly and deeply emarginate at apex, slightly conduplicate at base. Floral sheath ensiform, scarious, about 2 cm. long, 2.5–3 mm. wide. Pedicellate ovary arcuate, filiform, about 2.5 cm. long, less than 1 mm. thick. Flowers "greenish-white with pink on inside of tube" (*fide* collector), solitary, paired or few, successive, fugacious, about 4.5 cm. in diameter. Dorsal sepal about 2 cm. long, 1 mm. wide basally, narrowing to 0.25 mm. near apex, erect, twisted, 5-nervose. Lateral sepals similar in shape and size, about 2 mm. wide basally, spreading or downcurved, forming a triangular, obtuse mentum with the column-foot which is 4.5 mm. deep, the margins involute. Petals about 1 cm. long, 0.25 mm. or less wide, filiform, long-caudate, slightly broader basally. Lip 9 mm. long, 1.5–4.5 mm. broad when expanded, long unguiculate basally; lateral lobes erect at sides of column, deep purple when dry, elongate-triangular, obtuse or truncate, prominently nervose; midlobe very large, white suffused with pale yellow and with a deep purple area and venation near base which extends toward apex, basally oblong, enlarging into a spreading ellipsoidal portion with undulate and crisped margins at apex; median disc obscurely 3-lamellate and more or less furnished with clavellate papillae. Column 2.5 mm. long, blunt, with a foot; anther yellow when dry.

Mt. Beirut, 2,200 ft. alt.: on tree trunks in open, sunny places; abundant throughout the primary forest; flowers greenish-white with pink on inside of tube. August, 1950, *P. A. Adams* 7, TYPE, deposited in the Herbarium of the University of California at Berkeley (916872); Mt. Sankaku, 1,100 ft. alt.: on tree trunk, same sp. as #7. August, 1950, *P. A. Adams 30*. A sterile specimen, with living material growing in the Botanical Garden collections, obviously referable to this species.

This attractive dwarf *Diplocaulobium* is apparently closest to *D. nitidissimum* (Rchb.f.) Kraenzl., the type species of the genus and a native of the Admiralty Islands, the Solomon Islands, and New Ireland. The present plant differs materially from that species, however, in its rather larger dimensions in all parts, the shape of the labellum and other floral parts, and vegetative characters. Living material of this interesting addition to the Caroline orchid flora is in cultivation at the University of California.

Diplocaulobium elongaticolle (Schltr.) A. D. Hawkes, comb. nov.

Dendrobium elongaticolle Schltr., Engl. Bot. Jahrb. 56: 465, 1920.

A native of Koror and Babelthuap Islands in the Palaus, and of Yap.

Diplocaulobium flavicolle (Schltr.) A. D. Hawkes, comb. nov.

Dendrobium flavicolle Schltr. Engl. Bot. Jahrb. 56: 466, 1920.

Endemic on Ponape, having been discovered by Ledermann near Patapat (= Potopot) in 1913.

GEISSANTHERA Schlechter

In K. Schumann & Lauterbach, *Nachtr. Fl. Deutsch Südsee* 231, 1905.

The orchidaceous genus *Geissanthera* was established by Rudolph Schlechter in 1905 (*op. cit.*), the type species, *G. papuana*, having been collected in British New Guinea. In his revision of the Orchidaceae of New Guinea (1914) he reduced this genus to subgeneric status in *Microtatorchis* Schltr., making the type *M. papuana* (Schltr.) Schltr. Louis O. Williams reviewed certain species of the closely allied aggregation *Taeniophyllum* Bl. some years later (1939: 147) and came to the conclusion that *Geissanthera* should be placed in that polymorphic alliance, again as a subgenus. It is the opinion of the present writer that *Geissanthera* Schltr. constitutes a distinct generic entity, as was originally established by Schlechter.

P. A. Adams 4 is referable to *Microtatorchis Hosokawae* Fukuyama. The species was assigned by Fukuyama in his original diagnosis (1937: 903) to the section *Geissanthera* (Schltr.) Schltr. Inspection of this Ponapean endemic seems to indicate, however, that it is too aberrant in several diagnostic characters to warrant its retention in *Microtatorchis* Schltr.; it does, furthermore, agree in structure with *Geissanthera* Schltr., as it was initially described.

Microtatorchis Schltr. is a rather polymorphic group of predominantly epiphytic monopodial sarcanthad orchids with either leafy or aphyllous stems, very shortened inflorescences, and paired pollinia. *Geissanthera* Schltr. is distinguished with facility by the presence of large or small bracteoles on the inflorescence (virtually a unique character in the Orchidaceae), the proportionately large blossoms, and the bibrachiate clinandrium of the column. *Taeniophyllum* Bl., with which both of these entities have been confused, is now considered to include those totally aphyllous plants with four distinct pollinia and elongate, mostly filiform inflorescences, which are not bracteolate. The following dichotomous key will assist in the differentiation of the three genera involved:

1. Pollinia 4; plants totally aphyllous; inflorescences (at least the peduncles) proportionately elongate............. ....**Taeniophyllum** Bl.
   Pollinia 2; plants aphyllous or more or less leafy; inflorescences elongate or short..............................2
2. Inflorescences furnished with more or less prominent foliose bracteoles; clinandrium bibrachiate........... ....**Geissanthera** Schltr.
   Inflorescences bracteate, not furnished with bracteoles; clinandrium monobrachiate ......**Microtatorchis** Schltr.

The Ponapean species must be transferred to *Geissanthera*.

Geissanthera Hosokawae (Fukuyama) A. D. Hawkes, comb. nov.

Microtatorchis Hosokawae Fukuyama, Bot. Mag. [Tokyo] 51: 903, figs. 4, 5, 1937.

Taeniophyllum Hosokawae L. O. Wms., Harvard Univ., Bot. Mus. Leaflet 7: 147, 1939.

Mt. Tolotom, 2,100 ft. alt.: on mossy trees, associated with #1 (*Dendrobium violaceo-miniatum* Schltr.) and #5 (*Dendrobium nanarauticolum* Fukuyama). August, 1950, *P. A. Adams* 4.

The original specimen was collected by T. Hosokawa on Mt. Nanaraut (= Nanalaut), at about 500 meters altitude. The species is apparently restricted to Ponape in its distribution.

Geissanthera Schltr. reaches its greatest development in the montane regions of New Guinea, where about 14 species are known. Outlying representatives occur, in addition to the Caroline Island plant noted above, in Samoa and in the Philippines. All of the remaining species, except the typical *Geissanthera papuana* Schltr., have been described under *Microtatorchis* Schltr., and will need eventual transferral to the present group.

MOERENHOUTIA Blume

Orch. Archip. Ind. 99, tt. 28, 42, 1858.

The physurid genus *Moerenhoutia* Bl. is represented in the Carolines by four species, the present one being highly variable and with several apparently distinct varietal forms described.

Moerenhoutia leucantha Schltr., Engl. Bot. Jahrb. 56: 450, 1920.

Mt. Tolenkiup, 1,200 ft. alt.: in dense shade in very wet leaf mold of forest floor. Flowers white, terrestrial. August, 1950, *P. A. Adams 6*. Living material of this collection is in cultivation in our Botanical Garden.

The species is endemic on Ponape, and is closest in alliance with the New Guinean *Moerenhoutia constricta* J. J. Sm. and *M. lamellata* Schltr.

OBERONIA Lindley

Gen. & Sp. Orch., Pl. 15, 1830.

An exceedingly technical and difficult genus of paleotropical epiphytes, with two species present in the Adams collections.

Oberonia Hosokawae Fukuyama, Nat. Hist. Soc. Formosa, Trans. 31: 290, 1941.

Mt. Sankaku, 1,100 ft. alt.: with #26 (*Phreatia ladronica* Tuyama), epiphytic, bloom not seen. August, 1950, *P. A. Adams 27*.

A member of the section *Scytoxiphium*, and one of the less attractive members of the genus, probably bearing pellucid-white or pale green flowers about 3 mm. in diameter.

Oberonia ponapensis Tuyama, Bot. Mag. [Tokyo] 54: 275, 1940.

Mt. Tolotom, 2,100 ft. alt.: epiphytic, inflorescence rusty red. August, 1950, *P. A. Adams 17*.

An interesting dwarf member of section *Otoglossum*, apparently endemic on Ponape. The very numerous flowers measure 1 mm. or less in diameter, and when dry are an attractive orange hue.

PHAIUS Loureiro

Fl. Cochinch. 529, 1790.

A single species of this genus is known to date from the Carolines. The original material of the present species in the area was gathered by Ledermann on Ponape, near Patapat (=Potopot) and Paue (=Poaipoai).

Phaius amboinensis Bl., Mus. Bot. Lugd.-Bat. 2: 180, 1856.

Mt. Tolotom, 1,900 ft. alt.: terrestrial, in wet loam with much leaf mold, in deep shade. Abundant from about 1,500 ft. alt. up to summit. Flower pure white with creamy yellow tube. August, 1950, *P. A. Adams 11*. A handsome species, of considerable horticultural value.

PHREATIA Lindley

Gen. & Sp. Orch. Pl. 63, 1830.

With the interesting plant described here as new, the total number of Phreatias known to occur in the Caroline Islands reaches 10. The others are *Phreatia palawensis* (Schltr.) Tuyama, *P. pseudo-Thompsonii* Tuyama, *P. kusaiensis* Tuyama, *P. pacifica* Fukuyama, *P. Kanehirae* Fukuyama, *P. Thompsonii* Ames, *P. carolinensis* Schltr., *P. ladronica* Tuyama, and *P. ponapensis* Schltr. The genus is a large and exceedingly complex one, and stands sorely in need of critical revision.

Phreatia Goodspeediana A. D. Hawkes, sp. nov. (§ *Euphreatia*)

Herba parva epiphytica caespitosa, usque ad 6.5 cm. alta. Rhizoma abbreviatissima, cataphyllis scariosis obtecta. Caules fere deficientes. Folia parva, 4.5–6.5 cm. longa, 3–4.5 mm. lata, rigide erecta, coriacea, lineari-ligulata, obtusa vel apiculata, inaequaliter bilobata, basi pseudopetiolata articulata, vagina ca. 6 mm. longa, 3–3.5 mm. lata, scariosa, conduplicata. Inflorescentia 5 cm. longa, lateralis, erecta, apice valde reflexa, secunda, apice racemosa. Bracteae erectae, 5 mm. longae, basi 1 mm. latae, lineari-ensiformae, longe-acuminatae, apice leviter tortuosae. Flores 1 mm. longi, numerosi, fragili. Sepalum dorsale ovatum, acuminatum, 1 mm. longum, 0.25 mm. latum. Sepala lateralia ovato-elliptica usque ad obovata, acuminata, 1 mm. longa, ca. 0.5 mm. lata. Petala ovata, acuto-acuminata, leviter inflecta, 0.25 mm. longa, insigniter minus lata. Labellum 1.25 mm. longum, ca. 0.75 mm. latum expansum, obscure trilobulatum, oblongo-ellipticum, obtuso-apiculatum, disco leviter crasso.

Dwarf caespitose epiphytic herb to 6.5 cm. tall when in flower. Rhizome very abbreviated, obscured by sheathing scarious deteriorating bracts and copious flexuose slender roots. Stems mostly absent. Leaves few (6 in our specimen), 4.5–6.5 cm. long, 3–4.5 mm. broad, mostly rigidly erect, coriaceous, linear-ligulate, obtuse to apiculate and unequally bilobate apically, pseudopetiolate basally and articulate there, the basal sheathing portion about 6 mm. long and 3–3.5 mm. broad, scarious, conduplicate. Inflorescence 5 cm. long, lateral, erect, the tip sharply reflexed, mostly secund, apical portion racemose. Floral bracts mostly erect, 5 mm. long, less than 1 mm. broad at base, linear-ensiform, long-acuminate, the apex rather tortuose. Pedicellate ovaries vaguely arcuate, 1.25 mm. long. Flowers 1 mm. long, "translucent green" [*fide* collector], numerous, fragile in texture. Dorsal sepal ovate, acuminate, 1 mm. long, 0.25 mm. broad. Lateral sepals ovate-elliptic to obovate, acuminate, 1 mm. long, about 0.5 mm. broad, minutely coherent basally, forming a blunt mentum about 0.5 mm. long. Petals ovate, acute-acuminate, slightly upcurving, 0.25 mm. long, much less broad. Lip 1.25 mm. long, about 0.75 mm. broad when expanded, obscurely trilobulate, oblong-elliptic, somewhat bluntly apiculate, with a single median thickening on the disc.

Mt. Tolotom, 1,700 ft. alt.: on trunk of fallen hardwood, epiphytic. Flower translucent green. August, 1950, *P. A. Adams 2*, TYPE, deposited in the Herbarium of the University of California at Berkeley (916891). Living material is being grown in the collections of the Botanical Garden of the University of California at Berkeley.

Phreatia Goodspeediana is an unusual cluster-forming dwarf epiphyte of singular beauty. Its closest alliance is apparently with the Ponapean *P. pseudo-Thompsonii* Tuyama, though it differs from that species in its somewhat smaller size, the secund inflorescence, smaller flowers of a green instead of white color, the segments of which are of different shape. It is with pleasure that I dedicate this attractive novelty to Dr. T. Harper Goodspeed, Professor of Botany and Director of the Botanical Garden of the University of California at Berkeley, through whose efforts and kindness the present collection of Ponapean Orchidaceae came into my hands.

Phreatia ladronica Tuyama, Bot. Mag. [Tokyo] 54: 277, 279, in clavi, 1940.

Mt. Sankaku, 1,100 ft. alt.: on tree trunks, with lichens, #27 (*Oberonia Hosokawae* Fukuyama), #24 (*Bulbophyllum Gibbonianum* Schltr.), and Bird's Nest Ferns (*Asplenium nidus* L.). Flower translucent green, epiphytic. August, 1950, *P. A. Adams 26*.

An unusually interesting species, the foliage of which, upon drying, becomes almost transparent. It was originally described from material collected on Mt. Tappotyo, on the island of Saipan, in the Marianas group. Our present specimen, of which living material is being grown in our Botanical Garden, differs slightly in dimensions and in the green instead of white flowers.

PSEUDERIA Schlechter

In Fedde, *Repert. Spec. Nov.*, Beihefte 1: 644, 1914.

Only a single species of this interesting and difficult genus is at present known from the Carolines. The type material was collected by Ledermann near Patapat (= Potopot) on Ponape in 1913; he also obtained additional specimens near Paue (= Poaipoai), on the same island. The species is known also from Babelthuap in the Palau group.

Pseuderia micronesiaca Schltr., Engl. Bot. Jahrb. 56: 473, 1920.

Mt. Kubersoh, 2,000 ft. alt.: on mossy tree trunks. Flowers pale green with brownish spots. This plant is common throughout the higher mountains, sometimes almost completely covering a whole tree. Base of stem always rooted in ground. August, 1950, *P. A. Adams 20*. The species is most closely allied with *Pseuderia frutex* Schltr., of New Guinea.

STERILE MATERIAL

Forty-five minutes up trail from Nanpil to Tolenkiup: on fallen tree. Abundant in primary forest from 1,000 ft. alt. (more or less) up. Flower not seen. August, 1950, *P. A. Adams 8.*

This plant, of which only a very fragmentary specimen is present in the collection, is probably referable to one of the sarcanthad genera (subtribe *Sarcanthinae*) which occur in these islands, *viz.*, *Chiloschista* Ldl., *Thrixspermum* Lour., *Luisia* Gaud., *Vandopsis* Pfitz., *Trichoglottis* Bl., *Robiquetia* Gaud., *Saccolabium* Bl., or *Sarcanthus* Ldl.

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Some Luminous Fishes of the Genera *Yarrella* and *Polyipnus*

YATA HANEDA[1]

FISHES OF THE GENUS *Polyipnus*, in the family Sternoptychiidae, and of the genus *Yarrella*, in the family Gonostomatidae, like some other deep-sea luminous fishes, are furnished with numerous luminous organs, which usually may be seen on the ventral surface of the body.

Yarrella (Goode and Bean) is a comparatively new genus, in some respects intermediate between the genera *Gonostoma* and *Porichthys*, and is so called in honor of the ichthyologist, William Yarrell, F.L.S. (1789–1856).

In Japan two species of this genus—*Yarrella blackfordi illustrius* McCulloch and *Yarrella blackfordi elongata* subsp. nov.—were reported by Matsubara (1938).

The type of the genus *Polyipnus* is *P. spinosus* Günther, which was obtained by the vessel "Challenger," between the Philippine Islands and Borneo, at a depth of 250 fathoms.

Many species of these two genera have been examined and described. The structure of their luminous organs has been known for some time, but little or no work has been done on the luminous phenomenon of these organs.

I have collected specimens of these fishes in Japan, in the bays of Tosa and Sagami, since 1935 and, with this living material, have been able to observe the phenomenon of their luminescence in the dark, to examine the structure of their luminous organs, and especially to determine whether or not the luminescence is due to luminous bacteria.

The two species upon which I report here are *Polyipnus stereope* Jordan and Starks and *Yarrella blackfordi illustrius* McCulloch. Usually most of these fishes are taken in deep water by trawlers, but occasionally they come up to the surface during the night. It was on such an occasion that I caught *Polyipnus stereope* near the coast of Suzukawa, in the Prefecture of Shizuoka, by means of the Zibiki-Ami (the Japanese name for a large seine net). This procedure enabled me to study this fish alive, in the dark.

I have never been able to take *Yarrella* actually alive, but, although my specimens were all dead, they were nevertheless quite fresh, having been just caught in the trawlers' nets.

The principal type of luminous organ consists of two components. As a rough generalization, one part is a bulb-shaped body lying within the muscle of the fish, and the other part is a funnel, or parabola-like body, which is in contact with the surface of the body and arranged on its sides.

The structure of the luminous organs of these two species of fishes is much the same as that of other luminous deep-sea fishes such as *Sternoptyx*, *Argyropelecus*, and *Maurolicus*. It consists of five components as shown in Figure 1. These five components are a luminous body, a reflector, a color filter, a lens, and a pigment membrane.

Luminous Body

When sectioned medially, it is seen to consist of a mass of cells radiating from a central point appearing not unlike the closely packed

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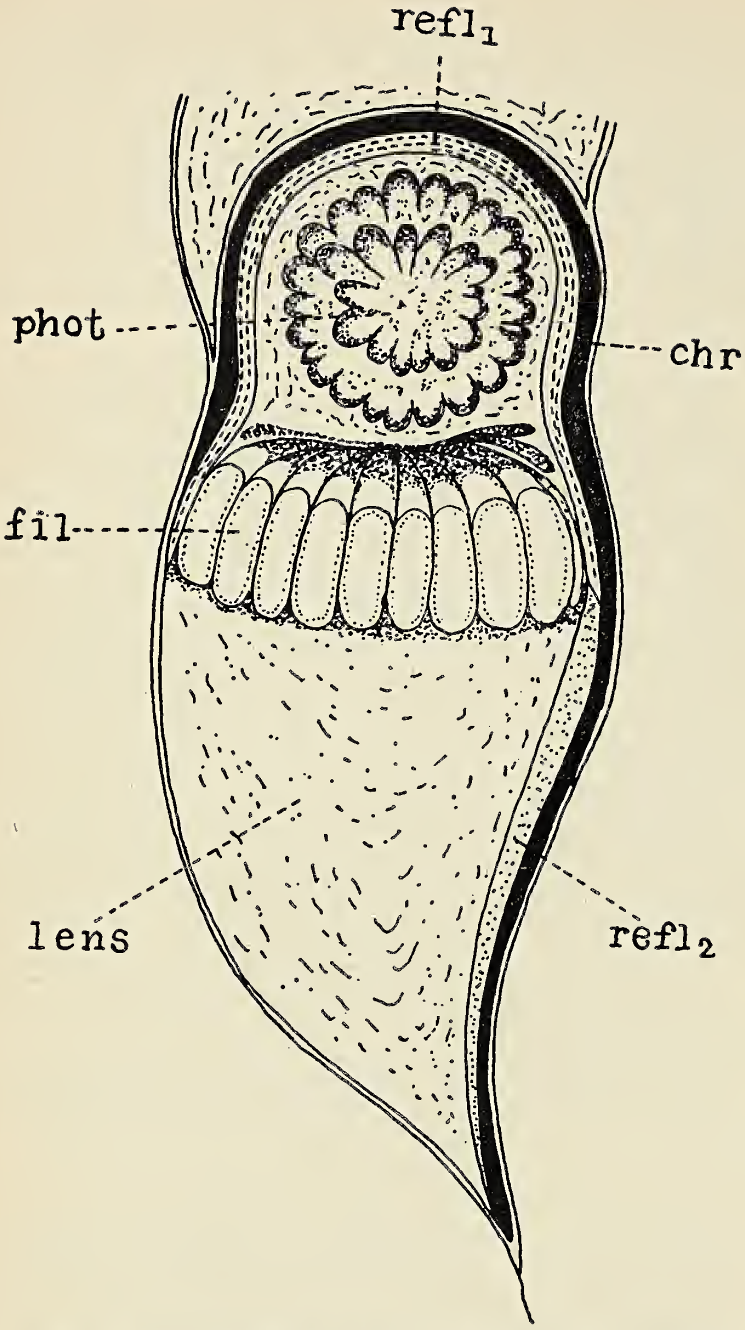

FIG. 1. Longitudinal section of the luminous organ of *Polyipnus stereope*. phot, Luminous body; refl$_1$, refl$_2$, reflectors; lens, lens; fil, color filter; chr, pigmented membrane.

seeds in a round seed capsule. When fresh material is cut with a thin knife, this organ appears to be milky blue and shows a bluish luminescence. This luminescence may continue for 4 to 5 hours after death. Sections cut from this organ stain well with haematoxylin.

Reflector

This consists of two parts. Part one (labeled refl.$_1$ in Fig. 1) covers the inside of the luminous body and the filter. It is a silvery, opaque membrane. Part two (refl.$_2$) covers the back of the lens and is composed of an arrangement of parallel fibers. Both parts reflect light extremely well.

Light Filter

Between the luminous body and the lens there is a transparent, single component which is beautifully colored. In *Polyipnus* and *Argyropelecus* it is a reddish violet. In *Yarrella* it is a ruby red. The color in some deep-sea luminous fishes is reproduced in "The Oceanic Fishes and Flat Fishes Collected in 1925–1927" by J. R. Norman (1930). *Argyropelecus* is shown as a reddish-violet color and *Bathytroctes rostratus* as orange. *Photichthys argentius* has a beautiful green color.

The tissues of this component are arranged in parallel, and its cells contain round nuclei and small granules. It may sometimes function as a lens, but it should be noted that both the curved upper and lower surfaces are parallel, the curves being in the same direction. Some investigators consider this component as the lens, but in my opinion it is simply a color filter.

These luminous organs *in situ*, when viewed ventrally by daylight, display a beautifully colored light in fresh specimens, but, if viewed laterally by daylight, this coloration can be seen localized only in this filter component and nowhere else.

I have examined living *Polyipnus stereope* in the dark, and have found the luminescence, as emitted, to be a greenish blue, whereas the color of the filter is violet. I was unable to obtain any living *Yarrella*, and am therefore unable to compare it with *Polyipnus*. The two species have filters of different color. One is violet and the other ruby red, and perhaps the color of their luminescence may be due to this difference in the color of their filters. However, owing to a lack of material for comparative purposes, I am unable to make any positive statement on this point.

Lens

The lens is a perfectly transparent, gelatin-like substance, and many investigators describe it simply as a mass of gelatinous substance without commenting on its shape. However, if fresh material is examined, the surface of the so-called simple mass of gelatin is convex, the body is swollen, and it has a definite shape. The only person to suggest that it might be a lens is Mangold (1910).

It is probable that most investigators have worked on preserved and dead material, and this may account for their failure to recognize it as a lens and to misunderstand its function. If the organ is put into alcohol or formalin, it contracts and becomes cloudy and shapeless, the sides shrink and become concave, and the coloring matter in the filter disappears. It is difficult to recognize the real function of the organ after such treatment.

Pigmented Membrane

This membrane covers the outside of the reflector. One of its functions is to assist the reflector, and another is to prevent light from being dissipated by entering the surrounding body muscle in which the organ lies.

Sometimes, the normally separate luminous organs are joined together to form a single luminous organ in the ventrothoracic region. Fine blood vessels enter through the reflector, ramifying in all directions within the luminous body and the filter. Nerves are also said to do the same, but I have not investigated this statement.

Unlike the Leiognathidae and other symbiotic luminous fishes which are able to control their display of luminescence by means of their chromatophores, *Polyipnus* and *Yarrella* are not provided with such structures. Nevertheless they can control it, but how they do so I am unable to say. Perhaps they are able to do it by means of their blood vessels or nerves.

These luminous organs are the closed type without any external openings and are unlike the open type possessed by the Gadidae (Kishitani, 1930), Macrouridae (Haneda, 1938), Monocentridae (Yasaki, 1928), Acropomatidae (Yasaki and Haneda, 1936), and Leiognathidae (Haneda, 1940), which possess external openings and are luminous by virtue of the luminous symbiotic bacteria within their open luminous organs.

I have been unable to find any bacteria, either luminous or non-luminous, in the organs of the *Yarrella* and *Polyipnus* fishes under discussion, in spite of an extensive search for them by the usual bacteriological methods. Luminous fishes with the closed type of luminous organs are true luminous fishes, and the luminosity which they display is the result of some product of the fishes' own creation and not the product of symbiotic bacteria living in the duct of the luminous organ of the fish.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to Dr. D. J. Pletsch, Scientific and Technical Division, ESS, GHQ, SCAP, who helped me to obtain publication of this paper.

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A New Genus of Seed-infesting Micropterygid Moths

L. J. Dumbleton[1]

The superfamily Micropterygoidea constitutes the most primitive group of the Lepidoptera. Like the other superfamily of the suborder Homoneura, the Hepialoidea, it is characterised by the venation in the fore and hind wings being almost identical. They are like certain Trichoptera in wing venation and in the presence in the pupae of large functional mandibles. The adult mouth parts show a gradation between the mandibulate type in the Micropterygidae and the haustellate type, characteristic of most Lepidoptera, in the Mnesarchaeidae. The Micropterygidae are of world-wide distribution and the larvae are external feeders on mosses and liverworts. The Eriocraniidae are not known from the Southern Hemisphere and their larvae are leaf miners on Betulaceae and Cupuliferae. The Mnesarchaeidae are confined to New Zealand, their larval habits being unknown. The Neopseustidae from India and Formosa are also unknown in their larval habits.

In February, 1947, I received some seed of *Agathis vitiensis*, a species of Kauri pine, from B. E. V. Parham of the Department of Agriculture of Fiji, with a request that I endeavour to rear out and identify the insect with which they were infested. Several of the larvae present pupated in September, 1948, and the pupal characters established the species as a micropterygoid moth. Parham also informed me that there was a similar larva in the seed of Queensland Kauri and A. R. Brimblecombe of the Queensland Department of Agriculture later sent me larvae and pupae of this species. The detailed morphology was studied with adult material extracted from the pupae. No success was obtained in attempts to secure emergence of the moths of the Fijian species and Brimblecombe was successful in obtaining emergence of the Queensland species only after many years of effort.

The association of these insects with Kauri pines (*Agathis* spp.) opens an interesting field for research since pines of this genus occur from the Philippines and Indo-China through the Malay Peninsula and Archipelago to New Guinea, the Solomon Islands, Eastern Queensland, New Caledonia, Fiji, and New Zealand. The genus *Agathis* is regarded as centred in Malaysia, and the Pacific representatives, of which *Agathis vitiensis* from Fiji is at the easternmost limit of distribution of the genus, are regarded as of Malaysian affinities and derivation. It seems likely that related micropterygoid moths will be found to be associated with *Agathis* elsewhere and particularly in Malaysia. There is at present no evidence of the occurrence of a related insect in the seed of the New Zealand Kauri (*Agathis australis*) or in those of the Moluccas, New Caledonia, Borneo, and the Philippines. The two species, one from Fiji and the other from Queensland, which I describe here, present points of considerable interest. The Fijian species is the first record of any micropterygoid moth from a really oceanic Pacific island although they are recorded from Formosa. The habit of feeding and pupating within

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seeds has not previously been reported within the superfamily.

These two species of micropterygoid moths are congeneric. The weight of evidence from morphological and biological sources would indicate that they are more nearly allied to the Micropterygidae than to the Eriocraniidae and, as they do not fit existing micropterygid genera, a new genus is created for them.

Agathiphaga new genus

ADULT: Ocelli absent; mandibles present; labial palps 4-segmented, sensory process on basal segment absent; maxillae with galea present but not modified to form short haustellum, lacinia present, maxillary palps 5-segmented. Forewings with Sc unbranched and with closed cubito-medial cell in addition to closed radial cell. Legs: Tibiae I with strigil at mid-length and a single short apical spur; tibiae II and III with two spurs at mid-length and two apical spurs; femora I and II with two small setae or spurs on tip. Male with paired glandular processes on fifth abdominal sternite. Male genitalia with claspers large, exserted and curved dorsad. Female genitalia eversible, terminal segment with single median Y-shaped rod, not heavily sclerotized or adapted for piercing.

PUPA: Head with four pairs of long frontal setae; beak absent. Mandibles hypertrophied, apex truncate with scalloped edge but without large teeth apically. Mandibles asymmetrical, both toothed externally but left mandible with single tooth on non-serrate ental margin. No strap-like process on dorsum of meso- and metathorax and first abdominal segment. All tarsi 2-clawed. No abdominal setae. Claspers of male genitalia exserted and curved dorsad.

LARVA: Antennae short. Compound eyes absent. Apodous. Integument spinulose, setae very short. Internal feeders in seed of *Agathis* spp.

GENOTYPE: *Agathiphaga vitiensis* n. sp. Fiji. *Agathiphaga* is separated from all other micropterygid genera by the presence of two apical spurs on the middle tibia, the absence of the sensory process on the basal joint of the labial palp, and (except for the Australian species of *Sabatinca*) the 4-segmented labial palps.

Agathiphaga vitiensis n. sp.

ADULT: Forewing 4.0 mm. long, dorsally dark greyish-brown with fine white hairs, a light yellowish-brown patch on anal area and a smaller patch of similar colour distad of this on the posterior margin before mid-length; ventrally dark scaled with lighter brown fringes. Venation as in Figure 3. Forewing with R_1 branched and Cu_{1a} arising from M_3. Lateral lobes of labrum with 3–4 setae on each side. Third and fourth segments of labial palps sub-equal in length. Apical segment of maxillary palp small, sub-globose. Male genitalia as in Figures 4*a–c*, 5*a–f*. Forked median rod of female genitalia 1.0 mm. long. Tooth on ental margin of left pupal mandible at about half-length, i.e., behind or cephalad of the external tooth.

SPECIMENS: Two male and three female pupae obtained from larvae within seed of *Agathis vitiensis*, Fiji, per B. E. V. Parham. *Holotype*, male, on slide mounts deposited in Entomology Section, Department of Agriculture, Suva, Fiji.

MORPHOLOGY

ADULT: The head capsule is strongly sclerotized and pigmented, with the exception of the stippled areas shown in Figure 1*a*, which bear the tufts of scales. A median epicranial suture runs from the posterior margin of the occiput to a point level with the antennal sockets. From the posterior third of the epicranial suture, a suture runs anterolaterally to a point behind mid-length of the inner margin of the eye. The ocelli are absent. The antennae are 5 mm. long and consist of about 47 segments of which the large basal one is 0.4 mm. long. The labrum (Fig. 1*b*) is tri-

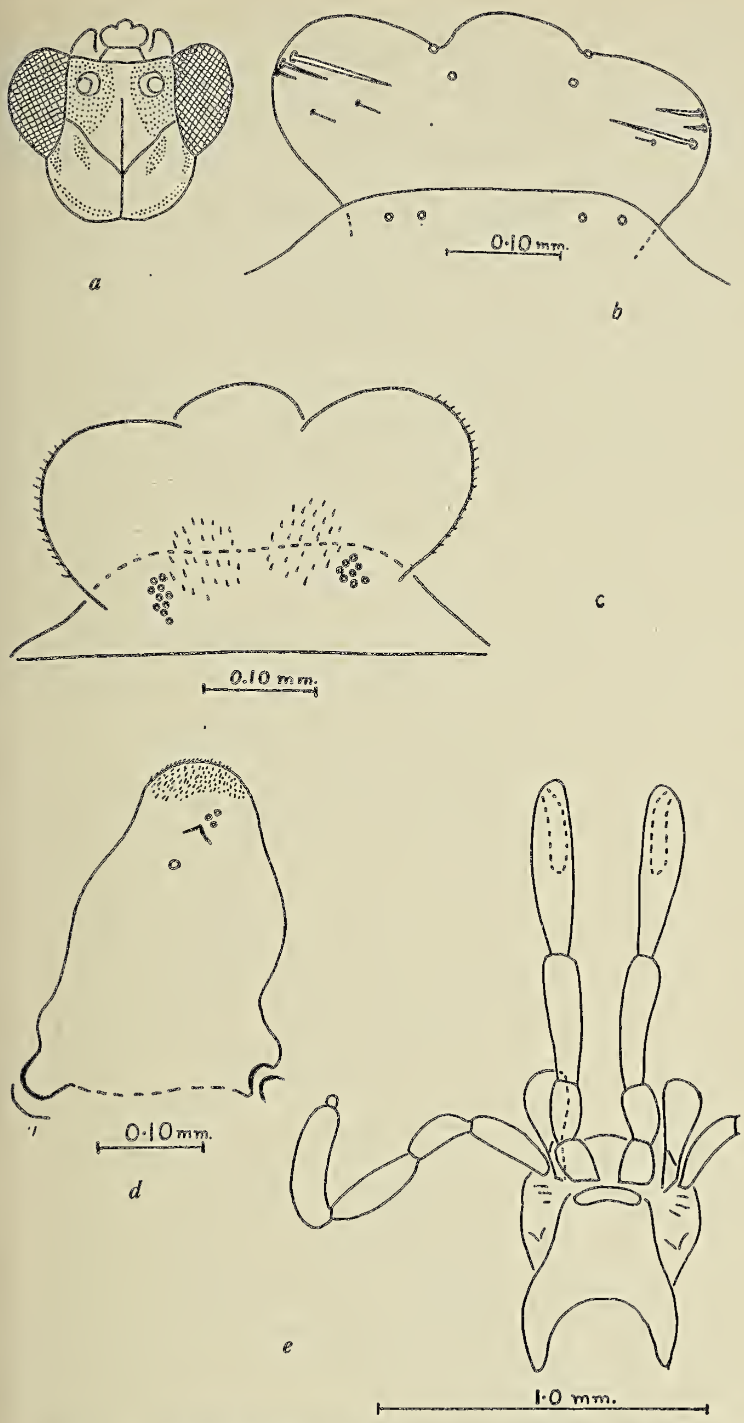

FIG. 1. *Agathiphaga vitiensis*, structures of adult. *a*, Dorsal aspect of head; *b*, dorsal aspect of labrum; *c*, epipharynx; *d*, external face of mandible; *e*, ventral view of labium.

lobed, with two sensory pores on each side between the lateral and median lobes, and one large and two smaller setae on each side at mid-length of the lateral lobe. The epipharynx (Fig. 1*c*) has a group of sensory pores on each side with scattered setae anterior to these. The clypeus or post-labrum has two sensory pores on each side. The mandibles (Fig. 1*d*) are present and, to the extent that the ginglymus and condyle are present, could be described as functional. They are reduced to a lobe or finger-like form and bear on the external face an obsolete but quite distinct tooth, with a large sensory pore basad of this and three smaller pores distad. There is a finely setose or spinulose area at the apex. The labium (Fig. 1*e*) has a transverse mental plate. The labial palpi are 4-segmented, the second segment slightly longer than the first, the third twice as long as the second, and the fourth slightly longer than the third with a sensory groove extending back to mid-length. There is no finger-like sensory process arising from the first segment of the palp. The hypopharynx is similar to that of *Agathiphaga queenslandensis* (Fig. 8*b*). The maxillary cardo and stipes (Fig. 2) are not clearly separated. The stipes bears mesally a sclerotized lacinia with a single dorsal seta; laterad of this is the thin leaf-like galea which is as long as the first joint of the maxillary palp. The maxillary palps are long, folded, and 5-segmented with the first, third, and fourth segments sub-equal in length, the second shorter, and the fifth small and sub-globose. The pattern on the forewing is shown in Figure 3*a* and the venation of both wings in Figures 3*b*, *c*. The unbroken lines represent veins in which the

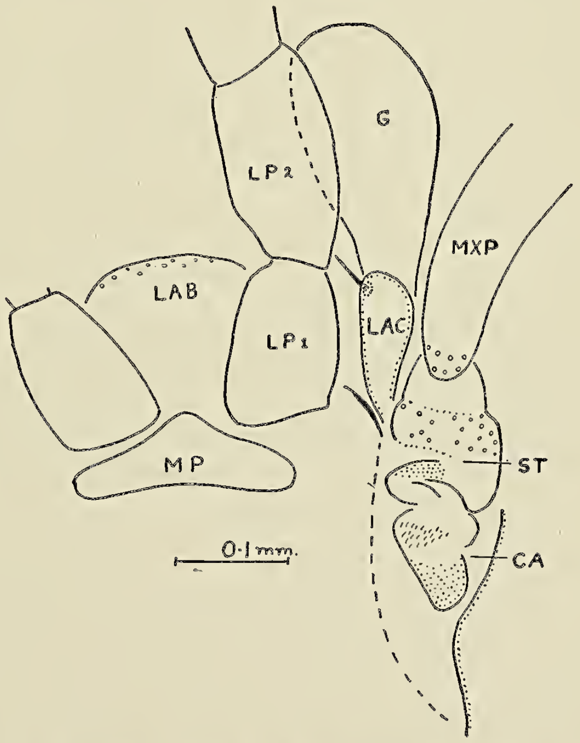

FIG. 2. Ventral view of maxilla and base of labium of adult *A. vitiensis*. MP, Mental plate; LAB, labium; LP1, LP2, segments of labial palp; CA, cardo; ST, stipes; LAC, lacinia; G, galea; MXP, first segment of maxillary palp.

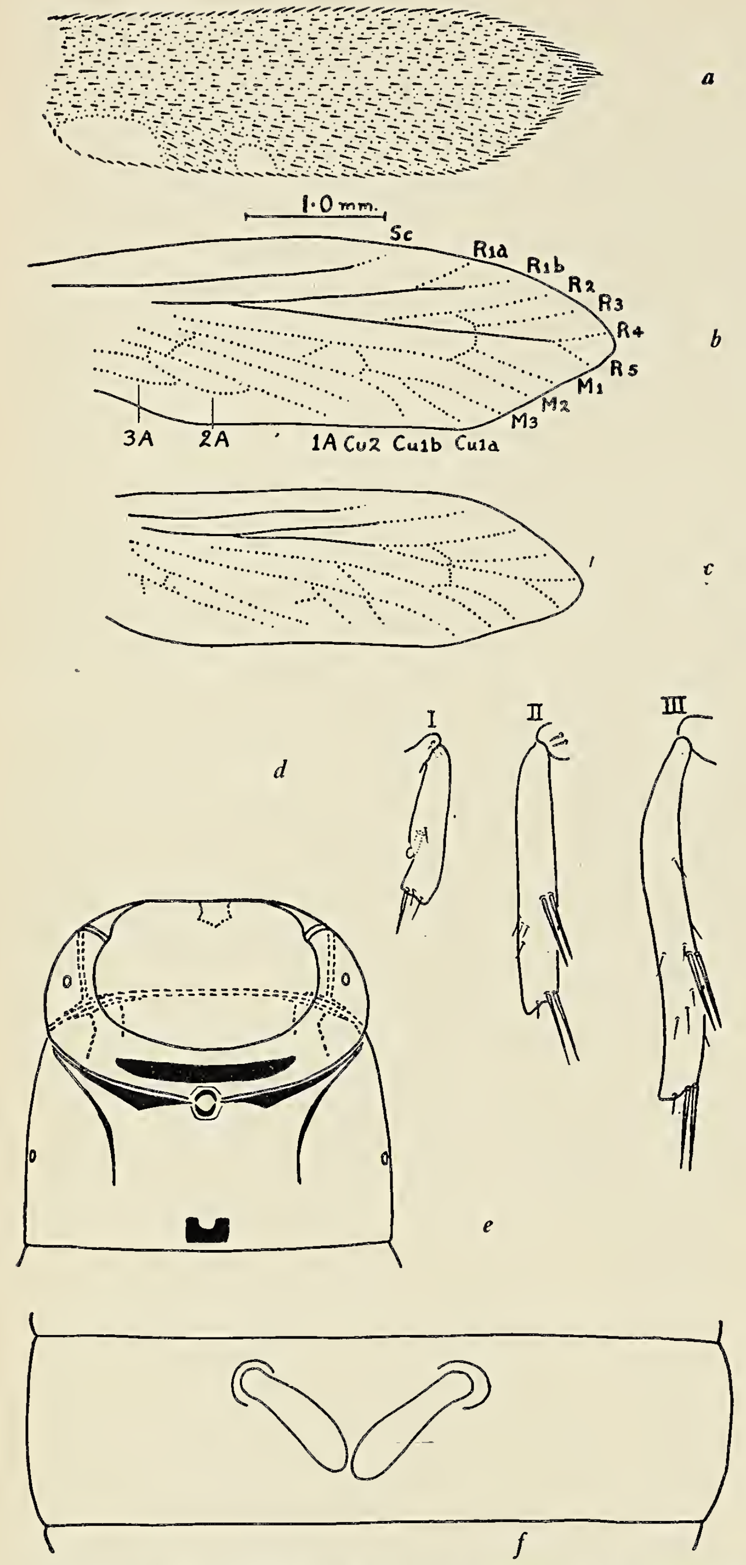

FIG. 3. Structures of adult *A. vitiensis. a*, Forewing showing markings; *b*, venation of forewing; *c*, venation of hind wing; *d*, pro-, meso-, and metatibiae; *e*, first and second abdominal segments in ventral view; *f*, fifth sternite of male showing glandular processes.

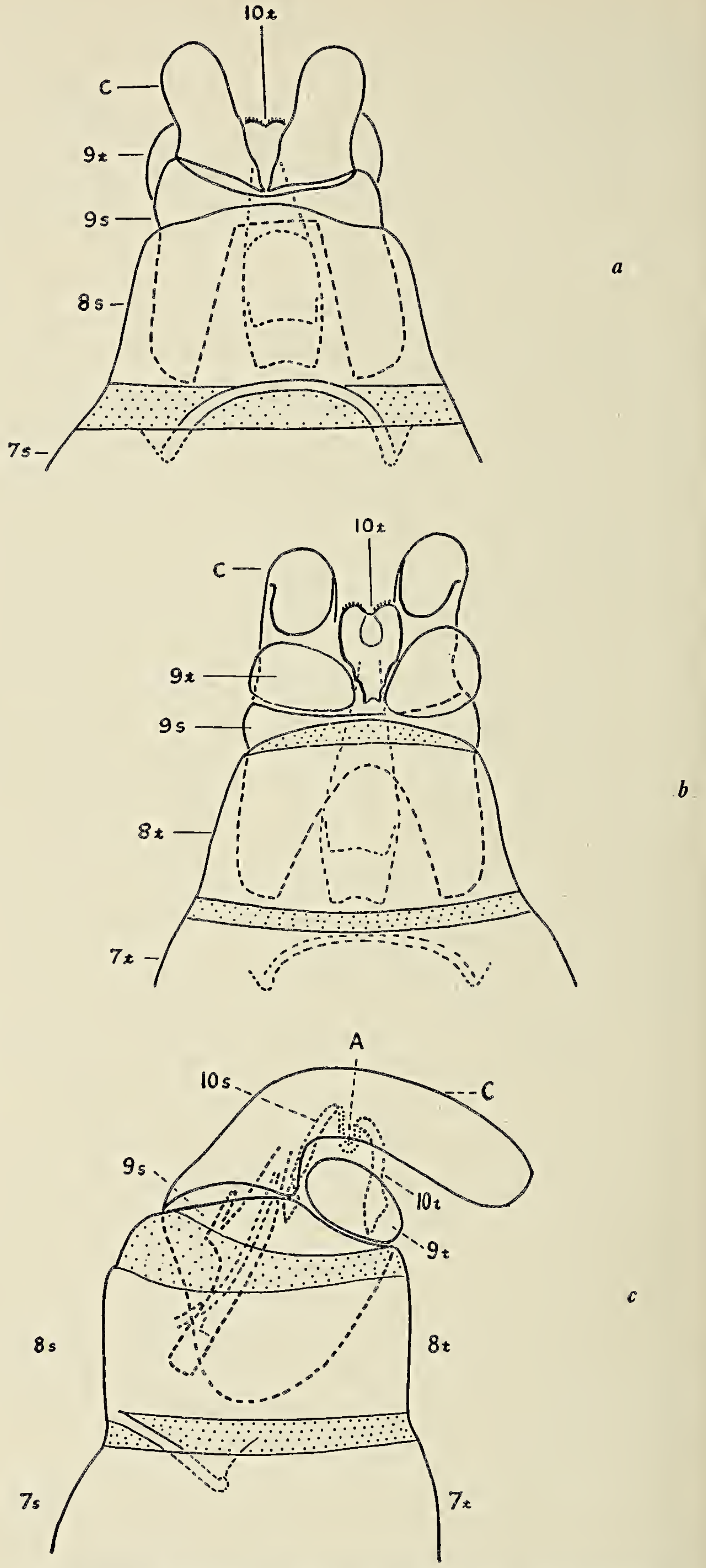

FIG. 4. *A. vitiensis*, terminal abdominal segments of male. *a*, Ventral; *b*, dorsal; *c*, lateral. 7s, 8s, 9s, 10s, Sternites; 7t, 8t, 9t, 10t, tergites; A, anus; C, clasper.

antecedent tracheation is still visible. The wing length given is that of the unexpanded wing removed from the adult within the pupa, and observations on the following species would indicate that the length of a normally expanded wing may be about 8 mm. The tibiae are shown in Figure 3*d*. The abdomen has eight unmodified segments with spiracles present on the first seven. Vestiges of spiracles are present on the eighth segment of the female. Dorsally the first abdominal segment (Fig. 3*e*) has a subpentagonal median sclerite anteriorly; laterad of this on each side is a stout rod-like longitudinal sclerite which, at its end on the posterior margin of the segment, has mesal and lateral branches. Ventrally the first sternite is much reduced, the

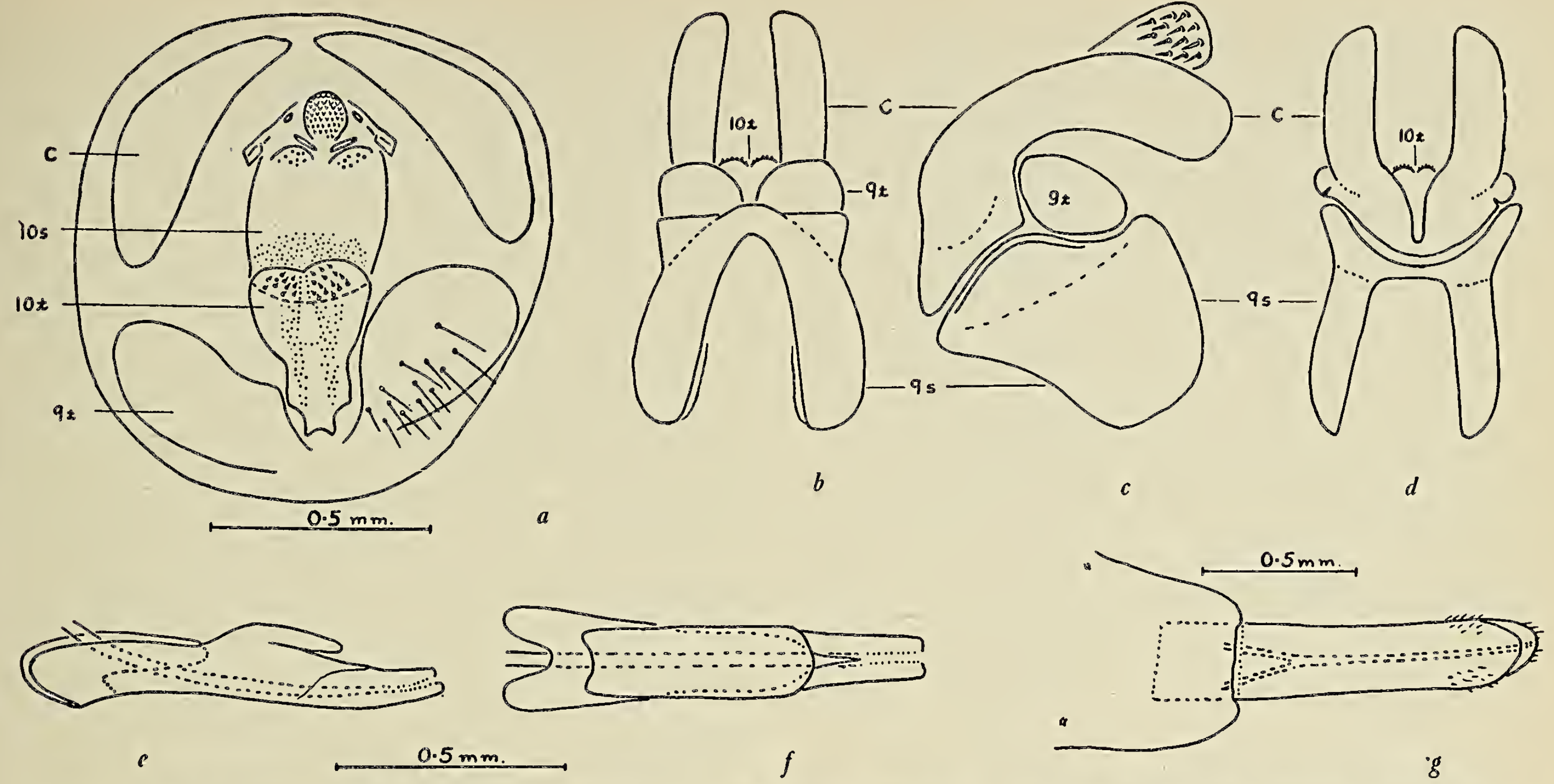

FIG. 5. *A. vitiensis*, male and female genitalia. *a–d*, Male: caudal, dorsal, lateral, and ventral aspects; *e*, *f*, aedeagus, lateral and ventral aspects; *g*, female. Abbreviations as in Fig. 4.

principal element being a narrow transverse sclerite. On the venter at the junction of the first and second abdominal segments the membrane is invaginated, and on the opposed surfaces are two elliptical sclerites, the tips of one articulating with those of the other and with the tip of a transverse sclerite on each side which is angular posteriorly. A narrow curved sclerite, or rod, runs from the anterolateral margin of the second sternite to a point midway between the median line and the spiracle. In a posteromedian position on the second sternite there is a small rectangular sclerite, concave anteriorly. On each side of the anterior margin of the second tergite, two short longitudinal sclerites, or rods, run posteriorly. In the male there is a pair of glandular processes (Fig. 3*f*) on the fifth sternite. Also in the male there are two lateral processes (Fig. 4*a*) from the anterior margin of the eighth sternite, which are withdrawn into the seventh segment.

In the male the basal piece of the genitalia (ninth sternite) forms a complete ring posteriorly (Fig. 4), but both dorsally and ventrally this piece is deeply emarginate, and the two lateral wings thus formed are deeply sunken within the eighth segment. Caudad of the basal piece on the dorsum are two paramedian lobes (9 t), and between and behind them is a grooved median pigmented sclerite (10 t) which is bilobed and bears short setae posteriorly (Fig. 5*a*). Between this and an opposing ventral sclerite is an invagination which may be the site of the anus. Between this sclerite (10 s), which has anteriorly a circular area with scale-like imbrications, and the bases of the claspers is the genital opening through which is protruded the aedeagus. The large claspers (Fig. 5*b–d*) have dense stout setae on their internal faces and articulate with the ventral part of the basal piece. The aedeagus is shown in Figure 5*e*, *f*.

In the female the ninth segment forms the long narrow ovipositor (Fig. 5*g*). It is strengthened by a single median rod which is forked anteriorly.

PUPA: The pupa is shown in dorsal and ventral views in Figure 6*a*, *b*. The mandibles are shown in Figure 6*c* and the clypeus and labrum in Figure 6*d*. There are two pairs of long setae or hairs on the frontal region and two pairs on the occipital region. The clypeus bears three setae on each side. The pupal skin of the type has nine setae on the labrum, four on one side and five on the other. There are

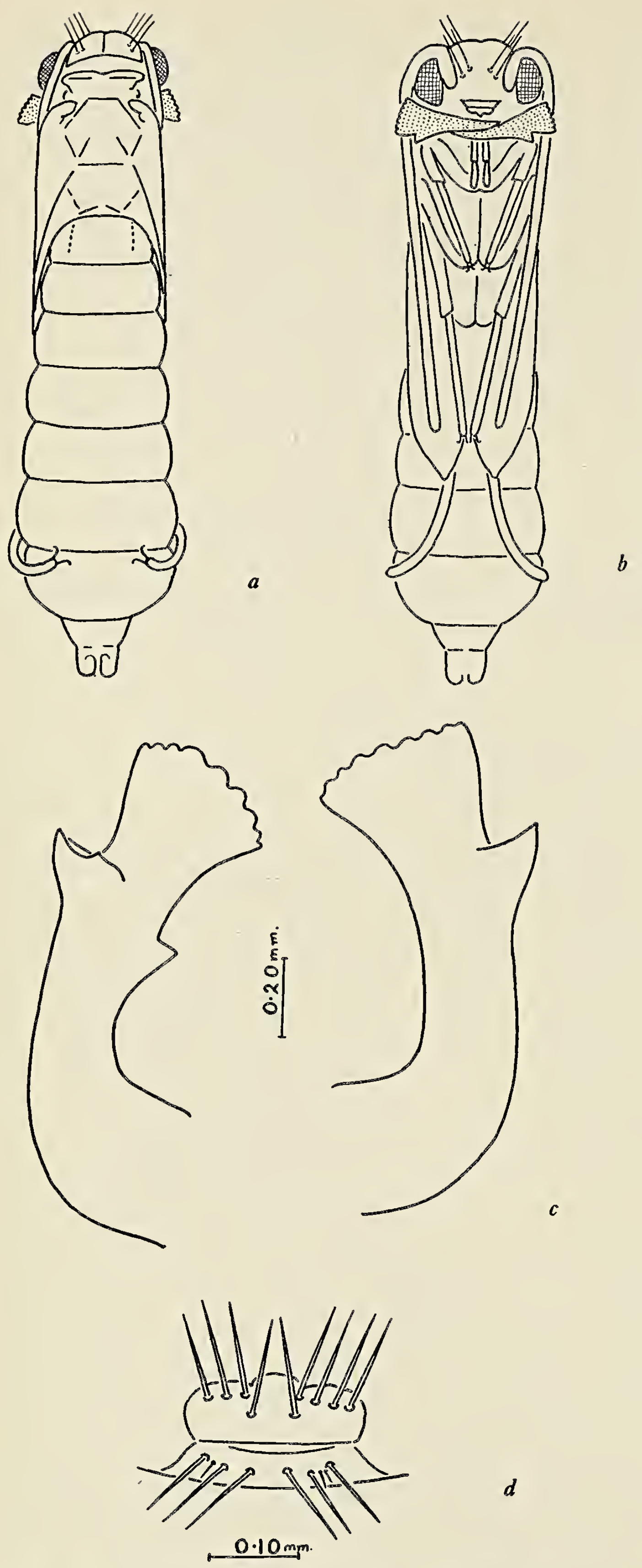

FIG. 6. Pupa of *A. vitiensis*. *a*, Dorsal aspect; *b*, ventral aspect; *c*, mandibles; *d*, clypeus and labrum, dorsal aspect.

no setae on the thorax and abdomen.

LARVA: The full-grown larva is 6 mm. long and 2.5 mm. wide. It is stoutly built and not flattened. The body width is more than twice that of the head capsule. Living larvae are yellowish in colour with the exception of the mouth frame and trophi, which are dark brown. Legs are absent. The thoracic and abdominal integument is finely and densely spinulose and without sclerotized or pigmented plates. Body setae are present but are small, and their arrangement is difficult to discern. There are nine pairs of spiracles, one prothoracic and eight abdominal. The head (Fig. 7*a*) is widest behind mid-length and is not flattened. It is emarginate posteriorly in the middorsal line where the epicranial halves meet. In both this and the following species, neither the frontal suture nor the adfrontal suture is evident, and I am unable to determine the position of the anterior tentorial pit. The disposition of the dorsal setae on the head is shown in Figure 7*a*. The antennae (Fig. 7*b*) are enclosed in a pigmented ring and consist of one prominent sclerotized and pigmented segment on the apex of which are borne three finger-like processes, three setae, and one seta with a thickened collar. External to and posteroventrad of the antennal ring is a pigmented spot probably representing an ocellus. The labrum (Fig. 7*c*) is transverse, slightly emarginate anteriorly, and bears four setae in a line across the disc and another seta behind these on each side of the lateral margin. On each side of the anterior margin are two setae with a third beneath them. The mandibles (Fig. 7*d*) are quadridentate and bear on the external face two setae. There is no bunch of long, branched hairs at the base of the cutting edge. Ventrally the head is deeply divided by the foramen (indicated by a broken line in Figure 7*a*) which consists of an anterior foramen separated by a slender tentorial bridge from the posterior foramen. Posteriorly the foramen (Fig. 7*e*) has on each side a triangular extension with the apex extending toward the posterolateral angle of the head capsule. The ventral mouth parts are shown in Figure 7*f*. The mentum bears no setae nor sensory pits and is separated from the maxillary stipes on each side by a pigmented bar. The labium is large and conical and bears posteriorly a pair of short setae and, anterior to these and somewhat farther apart,

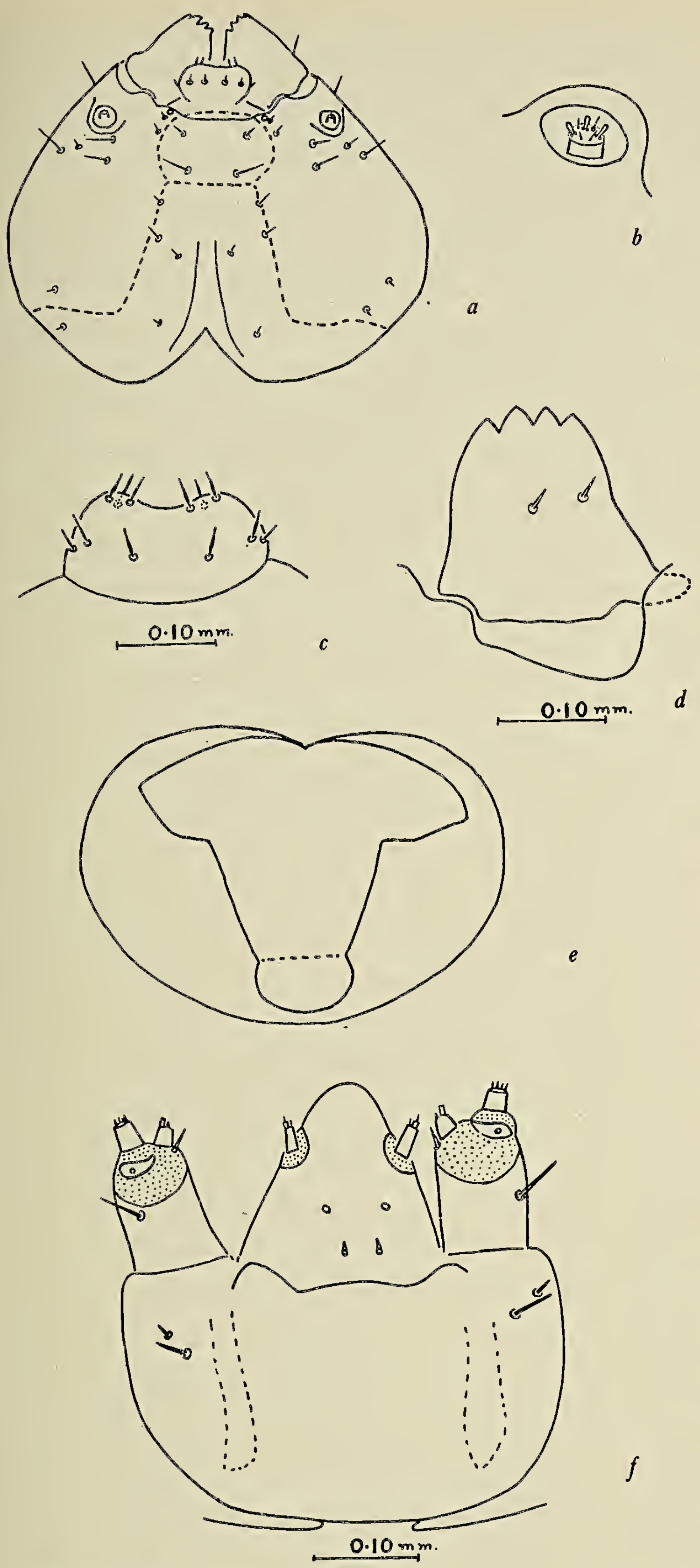

FIG. 7. Larval structure of *A. vitiensis. a*, Dorsal aspect of head; *b*, detail of antenna; *c*, dorsal aspect of labrum; *d*, mandible; *e*, caudal aspect of head capsule; *f*, ventral aspect of ventral mouth parts.

a pair of sensory pits. The labial stipites are not differentiated. The labial palp is 2-segmented, the basal segment is truncate-conical and pigmented and bears apically the small second segment and a small seta or process. The second segment bears a small process apically. The maxillary stipes bears two setae. The maxillary palpiger bears a single seta laterad at mid-length. The maxillary palp is 2-segmented. The basal joint is transverse with a single sensory pit, and the distal segment is cylindrical and bears processes apically. The lacinia is borne on the palpiger mesad of the maxillary palp and is 1-segmented with an apical process. At the base of the lacinia mesally are one or two spines, or processes, possibly representing the galea or digitus laciniae but smaller and shorter than that shown in *Mnemonica auricyanea* Wals. by Busck and Boving (1914: Pl. XI, Fig. 8). In general the larva is similar to that of *M. auricyanea.*

Agathiphaga queenslandensis n. sp.

ADULT: Unexpanded forewing of adult extracted from pupa 3 mm. long. Forewing of naturally emerged adult female 6.5 mm. long. Forewing unicolorous, without spots or pattern. Venation as in Figure 9*a*, *b*. Vein R_1 in forewing unbranched and Cu_{1a} arising from cubitomedial cell and not from M_3. Lateral lobes of labrum with numerous setae on each side. Fourth segment of labial palp short, conical, three or four times as long as wide. Forked median rod of female genitalia 0.6 mm. long. Male genitalia (aedeagus not seen) very similar to that of *Agathiphaga vitiensis.* Tooth on ental margin of left pupal mandible nearer apex than mid-length, i.e., nearly opposite external tooth.

SPECIMENS: Four female and one male pupae from seed of *Agathis robusta* from Como(?), Queensland, and several naturally emerged adults in poor condition from seed of *A. robusta* from Maryborough, all sent by A. R. Brimblecombe. *Holotype,* female, on slide mounts deposited in Queensland Museum, Brisbane, Australia.

MORPHOLOGY

ADULT: The adult of this species is generally similar to that of *Agathiphaga vitiensis,* except in size and in the absence of wing pattern. On the head the median epicranial suture is

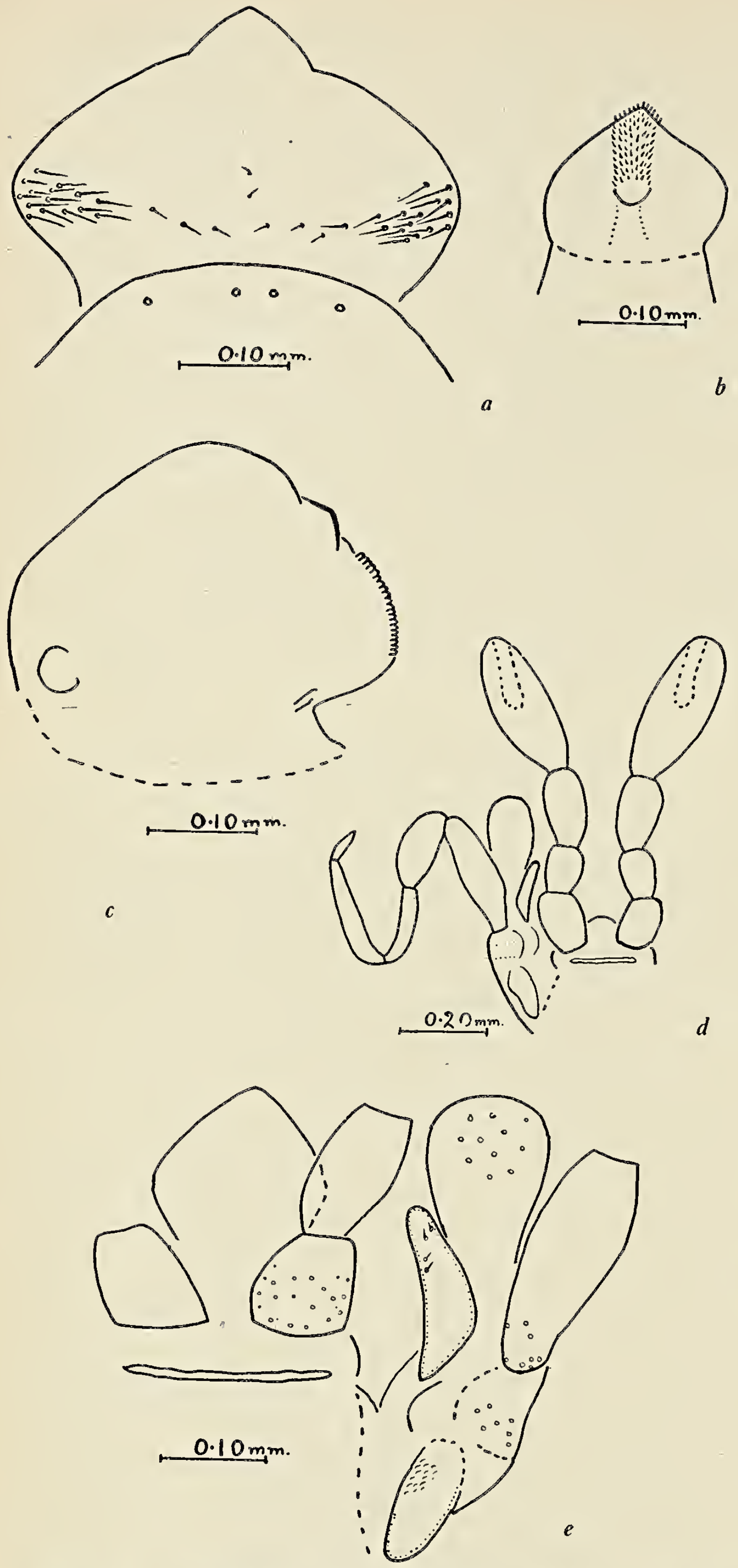

FIG. 8. *Agathiphaga queenslandensis*, structures of adult. *a*, Labrum, dorsal aspect; *b*, hypopharynx; *c*, mandible; *d*, labium and maxilla, ventral aspect; *e*, detail of maxilla and base of labium.

present but the two lateral sutures are absent. The unsclerotized scale-bearing areas are similar to those of *A. vitiensis*. The labrum (Fig. 8*a*) is distinguished by the more numerous setae, concentrated at the sides but extending across the disc. The epipharynx is similar to that of *A. vitiensis*. The mandibles (Fig. 8*c*) have an obsolete tooth and their apices have a finely toothed or crenellated area. The hypopharynx (Fig. 8*b*) has what appears to be an orifice at mid-length and, anterior to this, a broad median setose band. The mental plate is absent or represented by a very narrow transverse sclerite. The labial palps (Fig. 8*d*) are 4-segmented, the first and second subequal in length, the third one-half as long again and the fourth twice as long as the third with the sensory groove extending back to mid-length. The maxillae (Fig. 8*e*) have the lacinia present and bearing four short setae, galea present, maxillary palps 5-segmented and folded. The first and fourth segments are sub-equal, the second and third sub-equal and shorter than the first, the fifth short about one-third the length of the fourth, sub-conical and about three times as long as wide. The differences in the wing venation are seen in Figure 9*a*, *b*. The figures of the venation in this and in the preceding species are based on the study of the unexpanded wing of the adult extracted from the pupa. I was later able to study the wings of naturally emerged moths of *A. queenslandensis*. In the forewing the humeral vein is sometimes absent or indistinct. In one specimen Sc has a short branch. The cross vein Sc-R$_1$ is absent or indistinct. R$_5$ is 2-branched in some specimens as also is M$_3$. The cross veins Cu$_2$–Cu$_{1b}$ and 1A–Cu$_2$ are absent. In the hind wings I am unable to check the veins of the anal area owing to the condition of the specimens, but the rest of the wing coincides with the figure given. The female genitalia (Fig. 9*c*) are similar to those of *A. vitiensis*. The male genitalia are essentially similar to those of *A. vitiensis*. The aedeagus is missing in the single male specimen available. The principal differences are in the structure of the tenth tergite and tenth sternite (Fig. 9*d*).

PUPA: The main difference between *A. queenslandensis* and *A. vitiensis* is in the mandibles (Fig. 10*a*), as mentioned in the descriptions. The number of long setae on the clypeus and labrum is variable. In the pupal skin of the type there are only 4 setae asymmetrically arranged on the clypeus and 10 symmetrically arranged setae on the labrum. Another specimen has 6 setae on the clypeus and 10 on the labrum.

LARVA: The larva is very similar to that of *A. vitiensis* except in its smaller size. The main point of difference is in the shape of the lateral extensions of the posterior foramen (Fig. 10*b*) which are not triangular but ovoid owing to the constriction produced by dorsal and ventral processes from the epicranium. The only other difference is in the labral setae (Fig. 10*c*). On each side, at the anterior margin, two setae project anteriorly, while beneath these are two others instead of the single seta present in *A. vitiensis*. The mandible is shown in Figure 10*d*.

SYSTEMATIC POSITION

The Micropterygidae are characterised by the possession of functional toothed mandibles, a maxillary lacinia, and an unspecialised galea. One pupa, that of *Sabatinca incongruella* Walk., has been described by Tillyard (1923*a*: 445–448). It has a triangular mandible. The larvae of *Micropteryx calthella* L. and *M. aureatella* Scop. have been described by Chapman (1894: 341–344; 1916: 313) and that of *Sabatinca barbarica* Philp. by Tillyard (1923*a*: 440–445). These three larvae have long antennae, compound eyes (at least in *Sabatinca*), thoracic legs, abdominal prolegs, and flattened body processes. They are external feeders on mosses and liverworts. The family is represented in most regions of the world except the oceanic islands of the Pacific, the Australian and New Zealand representatives belonging to the genus *Sabatinca*.

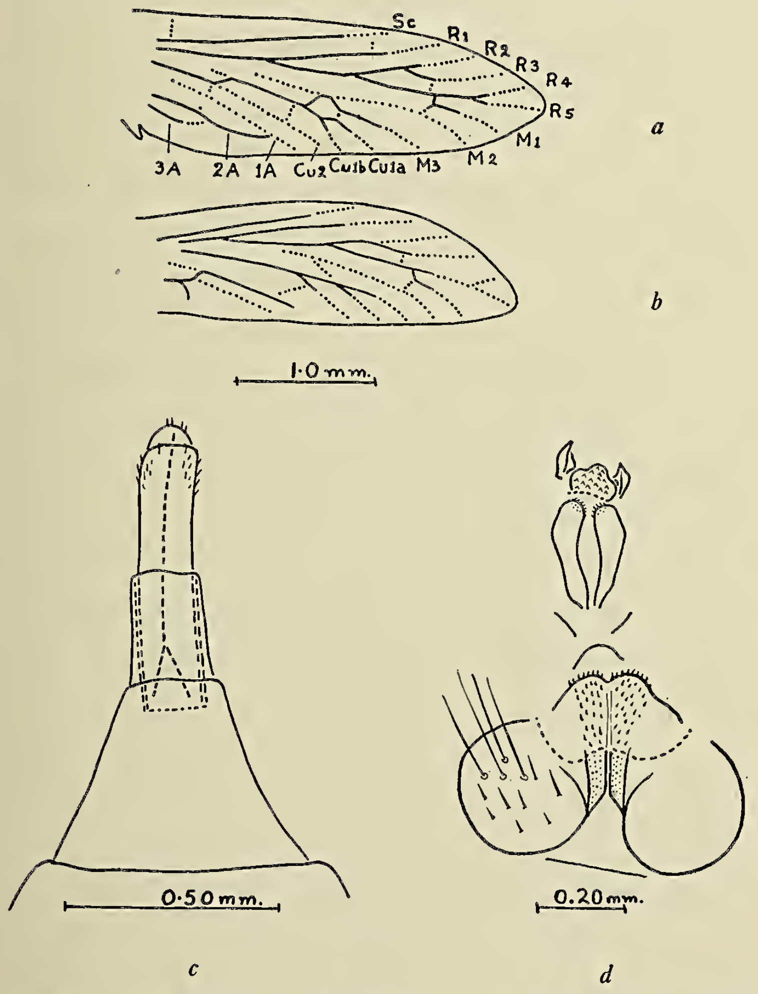

FIG. 9. Wings and genitalia of *A. queenslandensis*. *a*, Venation of forewing; *b*, venation of hind wing; *c*, female genitalia; *d*, male genitalia, caudal aspect (fragmentary).

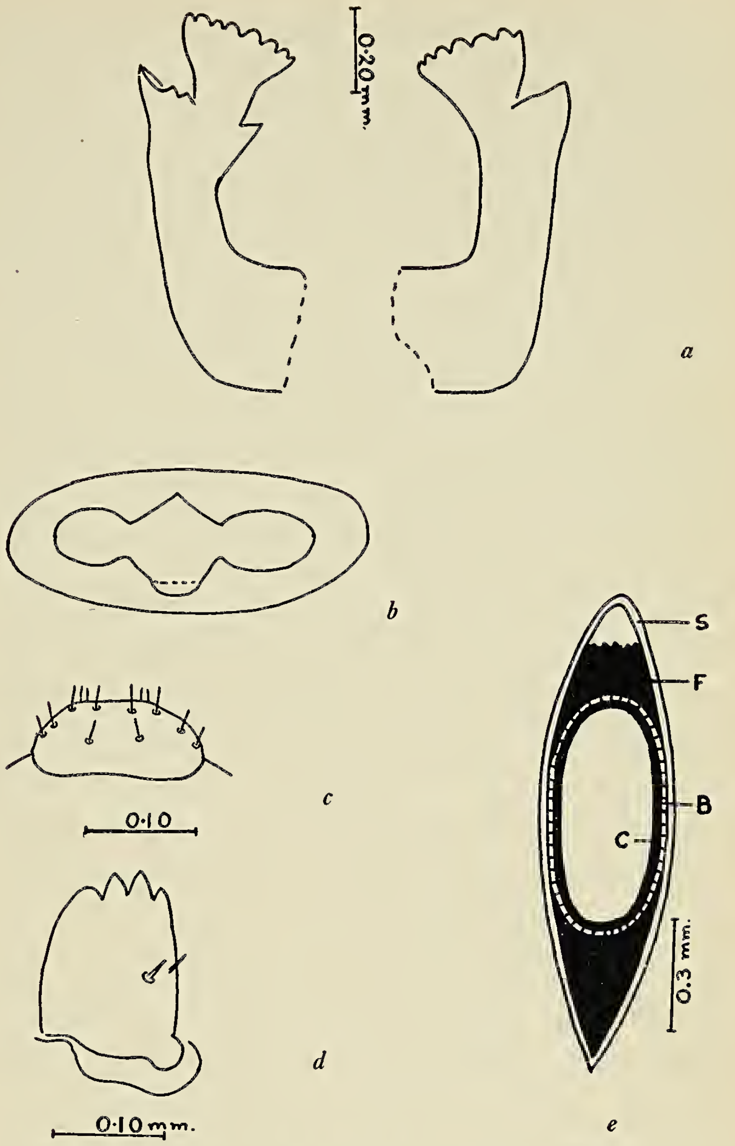

FIG. 10. Pupal and larval structures of *A. queenslandensis* and diagram of infested seed of host. *a*, Pupal mandibles; *b*, head capsule of larva, caudal aspect; *c*, labrum of larva, dorsal aspect; *d*, mandible of larva; *e*, longitudinal section (diagrammatic) of infested *Agathis* seed: B, buff layer; C, wall of pupal cell; F, filling material; S, seed coat.

The Eriocraniidae possess mandibles which are reduced and nonfunctional, the lacinia is absent, and the galea is modified to form a short haustellum. The pupa of *Eriocrania purpurella* Haw. has been described by Chapman (1893: 255–258) and that of *Mnemonica auricyanea* Wals. by Busck and Boving (1914: 155–158). They have truncate clubbed mandibles which are toothed or scalloped apically. The larva of *M. auricyanea* has been described by Busck and Boving (*op. cit.*), that of *Chapmania sparmanella* Bosc. by Grandi (1933: 145–150), and that of *Eriocrania sangi* Wood. by Jayewickereme (1940: 89). They have short antennae and simple body setae and the compound eyes, thoracic legs, and abdominal prolegs are absent. These larvae are leaf miners in the leaves of Betulaceae and Cupuliferae. The family is not represented in the Southern Hemisphere.

The Neopseustidae are said by Hering (1925: 143–147), who removed the genus *Neopseustis* from the Eriocraniidae, to lack the jugum and to have both mandibles and haustellum present. The larva and pupa are unknown as also is the food plant. The two known species occur in India and Formosa.

The Mnesarchaeidae have the mandibles and lacinia absent and the galea forming a long haustellum. The larva, pupa, and food plant are unknown. The family is confined to New Zealand.

The adult morphology of this superfamily, especially the mouth parts, venation, and genitalia, have been studied by Busck and Boving (1914), Tillyard (1919 and 1923*b*), Philpott (1924 and 1927), and Issiki (1931). As will be seen from the foregoing short account of the families, the larval and pupal stages and the food plants and habits of these insects are known in relatively few cases. In fact, Chapman's (1894: 337) comment, "I was much impressed with the resistance of the Eriocephalidae to investigation . . . I had little idea that they would continue this resistance for so many years," is still apropos.

Agathiphaga cannot be placed in the Mnesarchaeidae as defined by Tillyard (1926: 411–412), as the mandibles are present and the haustellum absent, and, while vein R_1 is unbranched in *A. queenslandensis*, R_2 and R_3 are separate veins in both *A. queenslandensis* and *A. vitiensis*. In Viette's (1947: 25) key to the families, *Agathiphaga* would run to the Neopseustidae, but it cannot be placed in this family because the jugum is present, there are two apical spurs on the middle tibiae, and the haustellum is absent. There is some evidence of affinity with the Eriocraniidae, such as the reduction of the mandibles, the presence of two apical spurs on the middle tibia, the absence of the sensory process of the basal segment of the labial palps, and the absence of the asymmetrical hair brushes on the epipharynx. The form of the pupal mandibles is similar to that of the known eriocraniid pupae. The larvae, with short antennae and no compound eyes, thoracic legs, abdominal prolegs, or flattened body processes, resemble the eriocraniids.

The genus appears to conform more closely with the Micropterygidae than with any of the other families. The mandibles, though reduced, are apparently functional and have at least one reduced tooth present, the maxillary lacinia is present, and the galea is present but not elongated. The radial cell is present, as it is in all micropterygid genera except *Palaeomicroides* and *Neomicropteryx*. It is also present, however, in the eriocraniid genus *Eriocraniella*.

Agathiphaga does not fit the emended family diagnosis of the Micropterygidae given by Issiki (1931: 1037–1038), in that ocelli are absent, and there is no branch of Sc. The sensory process on the labial palps, figured by Tillyard (1923*b*: 189) in *Sabatinca*, by Busck and Boving (1914: pl. xv, fig. 6) in *Micropteryx ammanella* Aub., and by Issiki (1931: 1035) in Japanese micropterygids, is absent, as are the epipharyngeal hair brushes figured by Tillyard (1923*b*: 183), and Issiki (1931: 1033). The female genital apparatus is unlike that of the micropterygids in the long exsertile ovipositor, but it lacks the cutting and piercing adaptations present in the Eriocraniidae.

The *Agathiphaga* pupa has four pairs of frontal hairs as against two pairs in the eriocraniids, but it lacks the lateral abdominal hairs. It also lacks the dorsal abdominal hairs of *E. purpurella* Haw. and the frontal beak and the strap-like band on the meso- and metathorax of *Mnemonica auricyanea* Wals. Tarsal claws are present in the *Agathiphaga* pupa but are not recorded in the two eriocraniid pupae. They are also present in some trichopterous pupae.

The larvae of *Agathiphaga*, as mentioned above, also differ from those of the other known micropterygids and approach the eriocraniid condition, but this could be a result of the specialised larval habitat.

Hinton (1946*a*: 1–4) has proposed a new classification for the Lepidoptera. The Micropterygidae are given ordinal rank as the Zeugloptera and are regarded as more primitive than the Trichoptera, which also retain ordinal rank. The Eriocraniidae remain with the Lepidoptera and, together with the Mnesarchaeidae, comprise the suborder Daconympha. The characters of *Agathiphaga*, intermediate as it is between the Micropterygidae and the Eriocraniidae, make it difficult to sustain the proposed classification.

The weight of morphological evidence is for the inclusion of *Agathiphaga* as a specialised genus of the Micropterygidae. The seed-infesting habit could have arisen as a specialised development of the micropterygids, and this is perhaps more likely than that it is a further development of the leaf-mining habit of the eriocraniids. Also the eriocraniids are not known to be represented in the Southern Hemisphere. Morphologically the adults of *Agathiphaga* are in several respects intermediate between the Micropterygidae and the Eriocraniidae, but whether *Agathiphaga* is on the direct line of evolution of the Eriocraniidae is uncertain. The fact that the food plant of *Agathiphaga* is also intermediate in the line of plant evolution between the known food plants of these two families cannot be regarded as significant in the absence of evidence as to the age of the association between insect and plant in each case.

BIOLOGY AND DISTRIBUTION OF AGATHIPHAGA

According to Petrie (undated: 14), the female cones of *Agathis robusta* are fertilized in September, but the seed takes 15 months to mature. At the same time, there are present on the tree the maturing cones of the previous crop, and these drop their seed in late December or early January. It is not known when the moths fly and lay their eggs or how long the larva is in the seed before it is fully fed. As the infested seed is not markedly smaller than uninfested seed, it might be assumed that the seed is not infested until it is nearly mature. Some support is given to this thesis by Petrie's note (undated: 13) that seed collected in October was apparently not infested whereas seed collected in December and January was infested. I have no information on the date of pupation of *A. queenslandensis*, but the larvae of *A. vitiensis* pupated in the spring. Petrie (undated: 9) notes that no external hole is seen in infested seed. The ovipositor of *A. queenslandensis* is not adapted for piercing the tissues of the cone, and it is likely that the eggs are laid on the cone surface, perhaps at the junction of contiguous scales, or thrust into crevices between the scales. The flaccid, yellowish, mature larvae are reported by Brimblecombe to be able to remain alive in the seed for as long as 3 years, but it is not known what factors terminate the diapause. Infested seeds (Fig. 10*e*) of *Agathis robusta* are completely hollowed out. At both ends of the seed is a filling, or plug, of hard black pitchy material. Between these is the pupal cell formed by a thin dark reddish-brown layer of uniform thickness, smooth on the inner surface. The external surface of this layer is pale brown or buff. The seed of *Agathis robusta* is 11 to 12 mm. long in the median line, and the pupal cell is 6 mm. long by 2.5 mm. wide and elongate-ovoid. Seeds from which *Agathiphaga queenslandensis* had emerged were kindly sent by Brimblecombe. They were found to have subcircular emergence holes 1.5 mm. in diameter.

It is doubtful if the tips of the long pupal mandibles can be apposed within the confines of the pupal chamber. The structure of the mandible makes it apparent that the emergence hole is made by a gouging or chiselling action of the teeth on the periphery of the circular, truncated, concave apex. Two holes are present in some seeds, indicating that the two mandibles may not be able to work at the one point on the wall of the pupal cell. The movement of the pupal mandibles must be produced by the muscles of the adult mandibles, in a manner similar to that described by Hinton (1946*b*: 284) in the pupa of the trichopteron *Rhyacophila dorsalis* Curt. The alternative is that torsional movements of the whole body enable the mandibles to make an emergence hole, and this seems very unlikely. It is evident from the material sent by Brimblecombe that the pupa emerges completely, or nearly so, from the seed before the emergence of the adult, since the pupal skins were free and not enclosed in the seed. The possession of tarsal claws by the pupa must greatly facilitate its emergence from the seed.

Brimblecombe informs me that *Agathiphaga queenslandensis* may destroy up to 20 per cent of the fertile seed of the Queensland Kauri Pine, *Agathis robusta*. Petrie (undated: 9) mentions a loss of the order of 90 per cent of the seed.

The seed of *Agathis palmerstoni* is also infested by *Agathiphaga*, but it is not clear whether this is *A. queenslandensis* or another species as I have not seen material which is definitely from *Agathis palmerstoni* seed. There was some doubt about the origin and identity of the seed recorded as from Como (?), but adults from this material, except for minor variation in the venation, were identical with those from *A. robusta* seed from Maryborough.

There is, of course, a possibility that *Agathiphaga* may infest the seeds of pines of the genus *Araucaria* which, in Queensland (but not in Fiji), occurs in the same areas as *Agathis*.

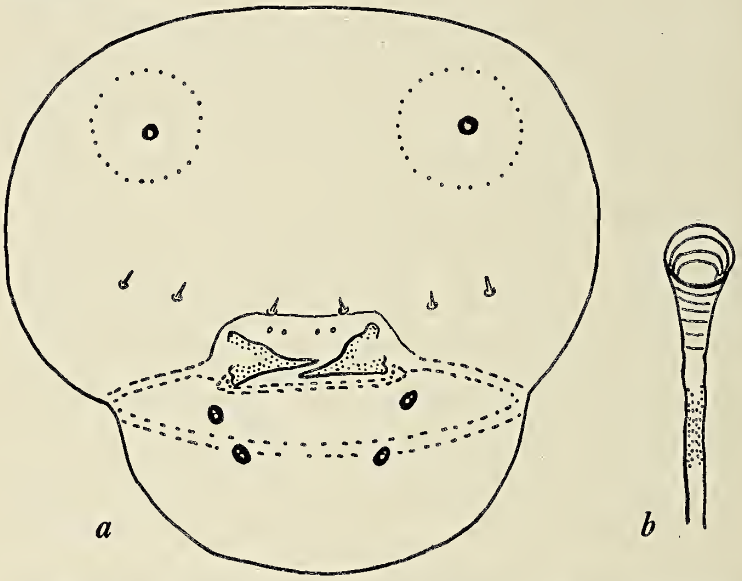

FIG. 11. Hymenopterous parasite of *A. queenslandensis*. *a*, Facial aspect of head of larva; *b*, larval spiracle.

A hymenopterous parasite attacks *Agathiphaga queenslandensis*. Two infested seeds were found to contain only the head capsule of the moth larva and four or five dead larvae of the parasite. The head capsule and the prothoracic spiracle of this parasitic larva are shown in Figure 11 to facilitate future identification. The parasitised larvae did not exceed 1 or 2 per cent of the total number examined. I have no information on the distribution of *Agathiphaga vitiensis* in Fiji or the extent to which it damages *Agathis vitiensis* seed there. Seeds containing living larvae were sent to me and 18 months later, in mid-September, pupae were present. No emergence of adults occurred even when the living pupae were removed from the seeds and kept in moist conditions, though the adults were fully developed inside the pupal case. The pupal head and forelegs were freely movable, but I did not observe any movement of the mandibles.

ACKNOWLEDGMENTS

It is a pleasure to record my thanks to Mr. Parham and Mr. Brimblecombe for the opportunity of studying these insects. My indebtedness to Mr. Brimblecombe for much information on the occurrence and habits of the Queensland species will be quite evident.

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Notes on Hawaiian species of *Scaevola* (Goodeniaceae)

Hawaiian Plant Studies 19[1]

HAROLD ST. JOHN[2]

GOODENIACEAE

Scaevola kauaiensis

(Degener) St. John, comb. nov.

Camphusia glabra (Hooker & Arnott) De Vriese, var. *kauaiensis* Degener, Fl. Hawaiiensis, fam. 340: text and fig. of flower and fruit on left of plate, Oct. 14, 1938, not *S. Gaudichaudiana* Cham. f. *kauaiensis* Skottsberg, Bernice P. Bishop Mus., Bul. 43: 27, 1927.

The genus *Scaevola* is well known in the Pacific, having littoral species widespread in the tropics, and more than 80 species in tropical Asia and the Pacific, but most of them in Australia and Oceania. The numerous species include various habit forms and a considerable range of morphological structure, but the genus has long been considered a clearly delimited and natural one. To be sure, the shrubs may be erect or scandent, the leaves alternate or opposite and glabrous or pubescent, the flowers solitary or in cymes, white striped, blue, purple, or yellow, and the drupes white or black, but these are properly considered specific differences and the genus is a natural, easily recognized one because of its tubular corolla with a split down its proximal side. From this large assemblage of species, various segregate genera have been proposed. Among these is *Camphusia* of De Vriese (1850),[3] based on the single Hawaiian species, *Scaevola glabra* Hooker & Arnott. This species is very distinct from all the other Hawaiian ones. In his subsequent monograph in 1854, De Vriese retained *Camphusia*, describing it in detail and giving as the key character the fact that its flowers were solitary. This character is of little value, as there are other dissimilar species which have solitary flowers: *S. Menziesiana* Chamisso, *S. coriacea* Nuttall, *S. Skottsbergii* St. John, etc. Degener (1938) revives the genus *Camphusia* and describes a new *C. glabra* var. *kauaiensis* with the sole character mentioned in the diagnosis being flowers twinned ("Flores gemini"), a character completely at variance with the key character chosen by De Vriese, "Flores solitarii." Degener in his English description mentions several other characters, such as length of peduncle, corolla, etc., but these are of varietal or specific significance only. Of course it is perfectly proper for a later author to redefine a genus and emphasize other characters as diagnostic. Degener does this for *Camphusia* De Vriese, separating it in his key as follows:

> "Corolla tube strongly curved and on upper side not split to base; filaments

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[1] This is the nineteenth of a series of papers designed to present descriptions, revisions, and records of Hawaiian plants. The preceding papers have been published in Bernice P. Bishop Mus., Occas. Papers 10(4), 1933; 10(12), 1934; 11(14), 1935; 12(8), 1936; 14(8), 1938; 15(1), 1939; 15(2), 1939; 15(22), 1940; 15(28), 1940; 17(12), 1943; Calif. Acad. Sci., Proc. IV, 25(16), 1946; Torrey Bot. Club, Bul. 72: 22–30, 1945; Lloydia 7: 265–274, 1944; Pacific Sci. 1(1): 5–20, 1947; Brittonia 6(4): 431–449, 1949; Gray Herb., Contrib. 165: 39–42, 1947; Pacific Sci. 3(4): 296–301, 1949; Pacific Sci. 4(4): 339–345, 1950; and Bernice P. Bishop Mus., Occas. Papers 20(6): 77–88, 1950.

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[3] In Nederl. Kruidk. Arch. 2: 148, 1850.

not marcescent; calyx not bracteate at base . . . . CAMPHUSIA

Corolla tube straight or nearly so and on upper side split to base; filaments early marcescent; calyx usually bibracteolate at base . . . . SCAEVOLA"

Among the Hawaiian species of *Scaevola*, the species *S. glabra* is conspicuous by having a strongly curved, fleshy corolla tube which is cleft on the proximal side only about halfway down and the calyx or hypanthium or base of the inferior ovary is naked or bractless at base. The question is, are these generic differences?

The corolla is cleft about halfway, but it has a suture from there down to the base on which it may split in age. This seems an extreme specific character, but not a generic one. The calyx or ovary is bractless at the base, but so also are the numerous flowers in the large cyme of *S. frutescens* (Miller) Krause of the Pacific and Indian Oceans, and so are they bractless in *S. Helmsii* E. Pritzel of Western Australia. The filaments of *S. glabra* are retained within the partly closed corolla tube and hence are little exposed. The filaments of most other *Scaevola* species are pushed outside as the slit tube of the corolla yields to the stress and turns to the anterior side and more or less flattens out, so the exposed filaments after anthesis wither and dry. However, no important difference between marcescent and non-marcescent filaments has been noted. The yellow color of the corolla is not unique, for other species have yellow flowers, as, for example, *S. enantophylla* F. von Mueller. Other species have their corollas of varying textures from membranous to fleshy, the Hawaiian species *S. coriacea* Nuttall having the whitish flowers of the 1- to 3-flowered cymes definitely fleshy. Other species, such as *S. tomentosa* Gaudichaud of Western Australia, have curved corollas. In some families the curving of the corolla provides good characters, but in *Scaevola*, with various species having the corolla tubes straight, nearly straight, or slightly or markedly curved, the attempt to set off one species as a segregate genus by the use of this character is patently unsound. The key and diagnostic characters used by Degener for *Camphusia* are judged equally invalid as the one of De Vriese. In conclusion, *Camphusia* seems correctly placed as a synonym of *Scaevola*, as it was by nearly all botanists and as it was in the monograph by Krause (1912: 119, 130) and by Skottsberg in his earlier writing (1927: 39), though in a later paper (1939: 184) there is an indication that he intends to restore *Camphusia*.

No specimens of any plant like *S. glabra* from the island of Maui are available. Krause lists one collected by Hillebrand and now in the herbarium at Wien. This has not been available for study, and, like Skottsberg and Degener, the writer has seen no recent collections from that area. If it really came from Maui, it might well be a distinct kind.

Since *S. kauaiensis* is here accepted as a species, it is desirable to print a description of it:

Shrub up to 4 m. tall; branches forking but often elongate and wand-like, the bark smooth, pale brown with raised corky lunate leaf scars and branch scars; branchlets smooth leafy, often for a considerable distance, stout, 1–15 mm. in diameter; axils with a prominent hairy tuft, the abundant hairs tawny, silky lanate, 6–7 mm. long, tardily deciduous after the fall of the leaves; leaves glabrous, alternate, or in part subopposite; petioles 12–40 mm. long; blades 5–12 cm. long, 15–55 mm. wide, coriaceous, oblanceolate to oval, the apex acute, the base cuneate or decurrent, above dark green, below pale green; cymes axillary, reduced, and 1- or 2-flowered; peduncle 2–10 mm. long, glabrous except for the hairy tufts at the apex; bracts 2, opposite, terminal, 2–4 mm. long, lanceolate to elliptic, fleshy, with their axils tawny hairy tufted; pedicels 7–35 mm. long, glabrous, ascending or spreading, bractless; hypanthium 4–6 mm. long, narrowly obpyramidal, glabrous; calyx lobes 5–8 mm. long, linear or, rarely, lance-linear; corolla yellow, fleshy, curved; corolla tube 28–35 mm. long, glabrous outside, but hirsutulous within from level of tip of calyx lobes to the throat, on proximal side cleft about halfway, and from the sinus to the base having a distinct suture along which the corolla may split in age; corolla lobes 6–15 mm. long, the outside glabrous, the inside hirsutulous except on the hyaline winged margins; filaments glabrous, about 33 mm. long; anthers 5 mm. long, linear; style 42–48 mm. long, exserted, stout, glabrous; indusium 3–4 mm. in diameter, ciliolate on the rim; drupe 16–20 mm. long, broadly oval, shining black; endocarp 9–13 mm. long, 8–9 mm. wide, 6 mm. thick, definitely flattened dorsiventrally, bearing several sharp ridges toward the apex, the walls in median cross section 0.5–0.8 mm. thick, smooth or with 1–2 slight ridges, stramineous.

RANGE: Swampy woods or high bogs at 3,500 to 4,700 feet altitude and the open bog of Alakai Swamp from the Kalalau Pali to Keaku Cave; also near Wahiawa Swamp at 2,100 feet altitude.

TYPE: Kauai, Waineke Swamp, Kokee, June 28, 1926, *Otto Degener and Henry Wiebke 2,187*.

SPECIMENS EXAMINED: All from Kauai: Kokee, *C. Skottsberg 1,020*; Kawaikoi Stream, *C. N. Forbes 908.K;* Kalalau Pali, *C. N. Forbes 1,037.K;* n. w. end Alakai Swamp, *H. St. John et al. 10,736;* Kauluwehi, *J. F. Rock 12,914;* central plateau, trail to Kaluiti stream and Keaku cave, *J. F. Rock 5,063* (also duplicates under the temporary numbers *5,075*, *5,077*, and *5,078*); Kaholuamanoa [=Kaholuamanu], *A. A. Heller 2,806;* and near Wahiawa bog, *L. H. MacDaniels 619*.

The only collector recording the stature of the plant was MacDaniels and he gave it as "small tree, height 4 meters." The plant is a shrub rather than a tree.

The diagnostic characters of the two species are as follows:

S. kauaiensis (Degener) St. John has the branches often long and wand-like, leafy for some distance; axillary hairy tufts 6–7 mm. long; peduncle 2–10 mm. long; pedicel 7–35 mm. long; calyx lobes 5–8 mm. long, linear or rarely lance-linear; corolla tube 28–35 mm. long; corolla lobes hirsutulous within except on hyaline-winged margins; endocarp wall in median cross section 0.5–0.8 mm. thick, stramineous, the surface smooth or with 1–2 slight ridges.

S. glabra Hooker & Arnott has the branches, or at least the lateral ones, ascending with leaves crowded near the stem tips; axillary hairy tufts 3–5 mm. long; peduncle 0–3 mm. long; pedicel 13–30 mm. long; calyx lobes 2–5 mm. long, narrowly deltoid; corolla tube 15–24 mm. long; corolla lobes hirsutulous within only for a short distance just near the base in the submarginal areas; endocarp wall in median cross section 1–2 mm. thick, dark brown, the surface with several prominent sharp ridges.

Scaevola frutescens (Miller) Krause

Scaevola frutescens (Miller) Krause is distinguished from its varieties by having its leaves glabrous from the first or, if sparsely puberulent near the midrib below, then glabrate long before maturity. This species is common on the outer Leeward Islands of the Hawaiian Group, extending from Kure (Ocean) Island to Midway, Pearl and Hermes to Laysan. Then it occurs on Kauai near Nawiliwili Bay and inland on the slopes of the Haupu Range; and it has been found on Kahoolawe Island. On the shores of the other main Hawaiian Islands the plant occurs only as the var. *sericea*, which is abundant and widespread along the shores.

Scaevola frutescens (Miller) Krause, var. **sericea** (Forster f.) Merrill

S. frutescens forma *moomomiana* Degener & Greenwell, ex Degener Fl. Haw. 340: 12/1/49.

SPECIMENS EXAMINED: Molokai: Kaluakoi, Kawakui Road, 600 feet altitude, low bushes growing on sand dunes, Dec. 22, 1932, *H. St. John et al. 12,450.*

One of the commonest littoral plants is this widespread variety, known from many parts of the tropical Pacific. It occurs near the beach or the sea shores on all types of soil. It has not been reported far from the beach or at high elevation, hence, this locality at 600 feet altitude and 1¼ miles from the shore is worthy of record. At the shore there are extensive and large dunes of coral sand and shell sand at Moomomi, Molokai. Southwest by west from here is a broad strip up the foothills where the strong northeast trade winds blow the dunes before them right up the hillsides. These inland dunes climb to the crest of the ridge at 600 feet and partway down the declivity on the other side. They have, at least in part, the same vegetation as those of the coast, *Boerhavia diffusa*, *Scaevola*, *Ipomoea pes-caprae*, etc. They are doubtless saline enough in this arid area, and the plant seeds have been blown inland along with the sand. Though these inland localities are of striking interest, they are easily explained.

The writer has also observed this variety on Oahu at 500 feet altitude. This was near the crest of the Koolau Range, east of the King's Highway Pass, east of Makapuu Head Lighthouse, above the first beach in Waimanalo. Here the *Scaevola* is to be seen in gulches, nearly to the top of the divide. This is on the windward side of the island and is fully exposed. Here storm winds obviously are responsible for lifting salt spray, sand, and seeds of beach plants up the gullies on the face of the precipitous cliffs. The distance inland, however, is only a small fraction of a mile.

Degener has also observed and collected this shrub of the inland dunes and has recently described it as *S. frutescens* forma *moomomiana* Degener and Greenwell. Its only distinguishing characters were stated to be: "This brittle-leaved form has densely velvety leaves." The type specimen, *Degener 7,730*, is in the herbarium of the New York Botanical Garden. The writer studied the type in June, 1950, and found it a full sheet. The leaves are densely ascending white pilosulous above and below, a little more hairy and velvety than usual in the variety, but the hairs are of exactly the kind found on the leaves of var. *sericea.* The type has blades 3.5–10.0 cm. long, spatulate, and, when dried, thick and rigid, showing no evidence of having been brittle. The writer was unable to perceive brittleness as a usable character for this forma in the herbarium or in the type locality where he has observed this plant several times. There were also present three other collections from near the type locality, *Degener 7,728*, *7,729*, and *7,731;* in these, differences in the length and density of the pubescence were observed, but they and *7,730* did not seem separable on the pubescence alone. All are better referred to *S. frutescens* var. *sericea.*

Scaevola mollis Hooker & Arnott, forma ***albiflora*** (Degener & Greenwell) comb. nov.

S. mollis var. *albiflora* Degener & Greenwell, in Degener, Fl. Haw., fam. 340: 10/1/47.

Corolla white except for the violet margin of the sinus of the split tube.

TYPE: Oahu, "Shrubby, cloudy east slope near top; between Puu Kanehoa and Puu Kaua, Waianae Range, June 23, 1940, *Degener No. 17,643.*"

SPECIMENS EXAMINED: Puu Hapapa, Waianae Mts., southeast slope, among bushes near top, June 4, 1939, *Otto Degener & Emilio Ordonez 12,364;* Puu Kaaumakua, Koolau Range, Waipio, low forest near peak, 2,400 ft. alt., 1 m. shrub, Aug. 23, 1942, *Harold St. John and June Suzuki 20,312.*

The species, *Scaevola mollis*, is abundant in the Koolau Range, Oahu, occurring from the moist forest of the Ohia Zone up to the crest of the mountains in the Cloud Zone. It is readily distinguished from the other species on Oahu by having its leaves soft hairy beneath and by having its flowers blue, or more exactly, pale blue with the veins and sinus margin violet. It is a very distinct species and quite homogeneous.

Only recently has the species been known in the Waianae Mountains. Besides Degener's type specimen (of var. *albiflora*) from the Waianae Mts., he apparently has a second collection. Its label reads, "*Scaevola mollis* H. & A. forma nov. with white flowers or more likely somewhat hybridized with *S. Gaudichaudiana* Cham." It matches nicely our collection from the Koolau Range. In the leaf shape, size, toothing, permanent pubescence, inflorescence form, pubescence, flower structure, all details tally exactly with those of *S. mollis*. No indications of hybridity are apparent to the writer. *S. Gaudichaudiana* is so different in structure and appearance that it should leave some visible trace in a hybrid offspring besides the lack of pigment in the flower. In conclusion, there seems no evidence of a hybrid origin. The plants differ from the species only in the albino flowers, hence, are best classified as a color form.

Inter-tidal Zonation at Rangitoto Island, New Zealand.
(Studies in Inter-tidal Zonation 4.)[1]

J. A. CARNAHAN[2]

INTRODUCTION

THIS STUDY was undertaken to elucidate, if possible, the causative agents determining the distribution of inter-tidal plants and animals on the shores of Rangitoto Island. The work comprised an attempt to classify the inter-tidal communities, followed by an examination of tidal and other environmental factors.

I wish to thank Professor V. J. Chapman for his advice and criticism. My thanks are also due to Miss R. F. de Berg, Mr. V. W. Lindauer, Miss L. B. Moore, and Mr. J. E. Morton for assistance with identifications; to Mr. P. Carnahan for help with the instrument levelling; and to Mr. C. Harvey for preparing the graphs for reproduction. Finally, the work on Rangitoto was facilitated by the cooperation given by the Naval Department and by the staff at Rangitoto Naval Base.

DESCRIPTION OF LOCALITY

Rangitoto Island is situated in the southwest corner of the Hauraki Gulf, New Zealand, off the entrance to Auckland Harbour (Fig. 1). It is a roughly circular island, with a diameter of 3 miles. The western and southern coasts are about 3 miles from the mainland, while the adjoining island of Motutapu protects its eastern shores. Only the northern coast is exposed, but even this faces a gulf, not the open sea.

Rangitoto is a volcano which has been active in recent times. The greater part of the island consists of flow basalt and exhibits the characteristic low conical shape of such volcanoes. This portion is probably more or less contemporaneous with the Pleistocene basalt volcanoes which are of frequent occurrence in the Auckland metropolitan area. The final cinder cone within the original crater may have ceased activity within historic times.

The principal substratum is the basic lava which comprises the island volcano. Upon sheltered shores, this occurs as solid flows or as broken scoria (Fig. 2). On fairly exposed shores, the flows are somewhat broken and the scoria is waterwashed. On the more exposed northern coasts, the heavy surf raised by northeast winds has produced cliffing and boulder beaches.

Mud occurs as harbour silt beyond the termination of flows and scorias. It also appears wherever it is possible for sedimentation to take place. It is conspicuous in protected bays and inlets and on scoria shores. Minor, localised substrata are developed from "natural brick" (sedimentary material baked by contact with hot lava), sand, and shell.

TERMINOLOGY

The writer follows Chapman (1946) and Beveridge and Chapman (1950) in applying terrestrial plant ecological terminology to inter-tidal communities of plants and animals. This is based on the assumption of the cli-

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[1] This paper contains the substance of a thesis presented at Auckland University College for the degree of M.Sc., 1948.

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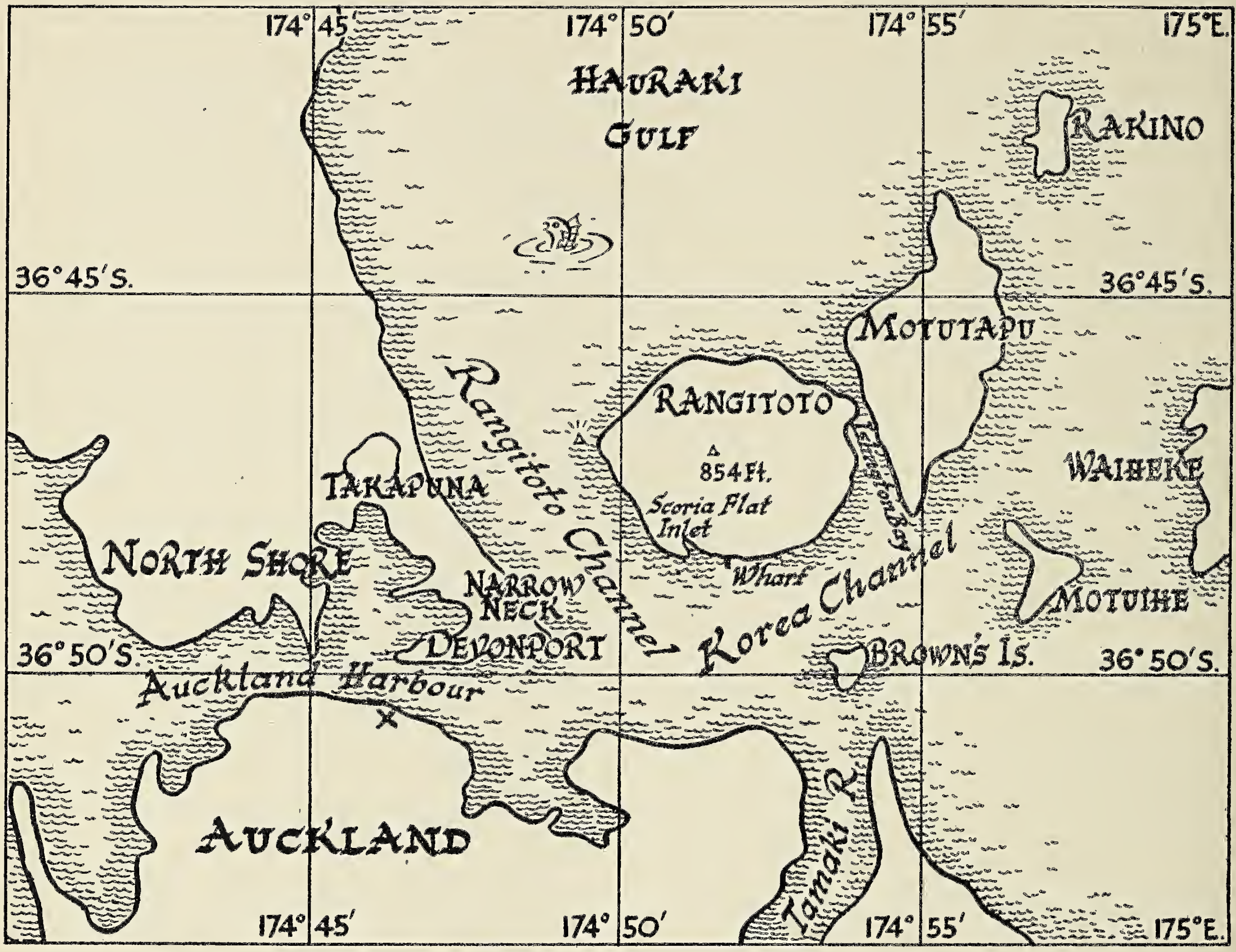

FIG. 1. Locality map of Rangitoto. Co-ordinates represent each 5 minutes of east longitude (top is north) and of south latitude. Scoria Flat Inlet shown west of Rangitoto Wharf. Position of Queen's Wharf indicated by X. (N. Z. Defence Dept.)

mactic nature of rocky-shore communities and the seral nature of those of salt marshes.

In the present paper, the littoral is defined as the region between mean high water mark and mean low water mark of spring tides. Above this is a lower supralittoral region subject to occasional submergence, and below it is an upper sublittoral region subject to occasional exposure.

In the following account reference is made to certain tide levels. These are abbreviated as follows:

E.H.W.S.T. (extreme high water mark of spring tides)
M.H.W.S.T. (mean high water spring tides)
M.H.W.N.T. (mean high water neap tides)
M.L.W.N.T. (mean low water neap tides)
M.L.W.S.T. (mean low water spring tides)
E.L.W.S.T. (extreme low water spring tides)

The abundance or frequency of a species in a community is noted as: d (dominant), a (abundant), f (frequent), o (occasional), or r (rare).

CLIMAX COMMUNITIES OF ROCKY SHORES

As the local variant of the basic zonation suggested by Stephenson (1939), Chapman (1950) proposes four basic formations for the rocky shore climax of New Zealand. These, in order from top to bottom of the littoral, are the Littorinoid, Barnacle, Lower Littoral Mixed Algal, and Sublittoral Brown Kelp formations. It appears possible to build the pattern of distribution of species at Rangitoto into this framework.

Littorinoid Formation

This formation is that of the uppermost littoral and lower supralittoral. Its communities may reach upwards to the highest levels ever submerged.

There is one principal association on rock, although several fasciations occur where there is sediment. The patchy nature of the communities of the upper littoral differs from the usual "closed" nature of littoral communities on Rangitoto.

1. Melarhaphe-Lichina association

Melarhaphe oliveri d
Lichina pygmaea d
Bostrychia mixta f
Ralfsia sp. f
Placoma vesiculosa f

Lichina has a narrower vertical range than that of *Melarhaphe*, its upper limit being at M.H.W.S.T. Its lower limit is that of *Melarhaphe*, in the vicinity of M.H.W.N.T.

Several subordinate species occur, scattered within similar limits to those of *Lichina*, e.g., turfs of *Bostrychia mixta* are frequent, and there are also an encrusting *Ralfsia* sp. and small colonies of *Placoma vesiculosa*.

2. Caloglossa-Catenella fasciation

Caloglossa leprieurii d
Catenella nipae d
Bostrychia mixta f
Hildenbrandia prototypus o

This community occurs within the levels of the *Melarhaphe-Lichina* association, where there is some sediment. It is found particularly in crevices and other shaded places, where *Hildenbrandia prototypus* also takes part in the community. *Caloglossa* and *Catenella* are also found, together with *Rhizoclonium hookeri*, on mangrove pneumatophores (see "*Avicennia officinalis* consocies").

3. Myxophycean fasciations

Several Myxophycean communities are associated with varying degrees of sedimentation in the high tidal levels. These are dominated by one or more of the following species: *Calothrix scopulorum*, *Lyngbya semiplena*, *Phormidium ambiguum*, and *Oscillatoria nigroviridis*.

Barnacle Formation

The communities within this formation occupy the large mid-tidal portion of the littoral (M.H.W.N.T.–M.L.W.N.T.). The two principal associations are characterised by the co-dominance of the barnacle *Chamaesipho columna*.

4. Chamaesipho-Apophlaea association

Chamaesipho columna d
Apophlaea sinclairii d
Gelidium pusillum f

This association occupies the upper portion of the mid-tidal levels. The lower limits of both dominants, as individuals, lie well below the lower limit of the association, but *Apophlaea* is dominant only within the limits of the association. The vertical range of *Gelidium pusillum*, a scattered, turf-like species, lies across that of the association.

5. Chamaesipho-Saxostrea association (Fig. 2)

Chamaesipho columna d
Saxostrea glomerata d
Elminius plicatus f

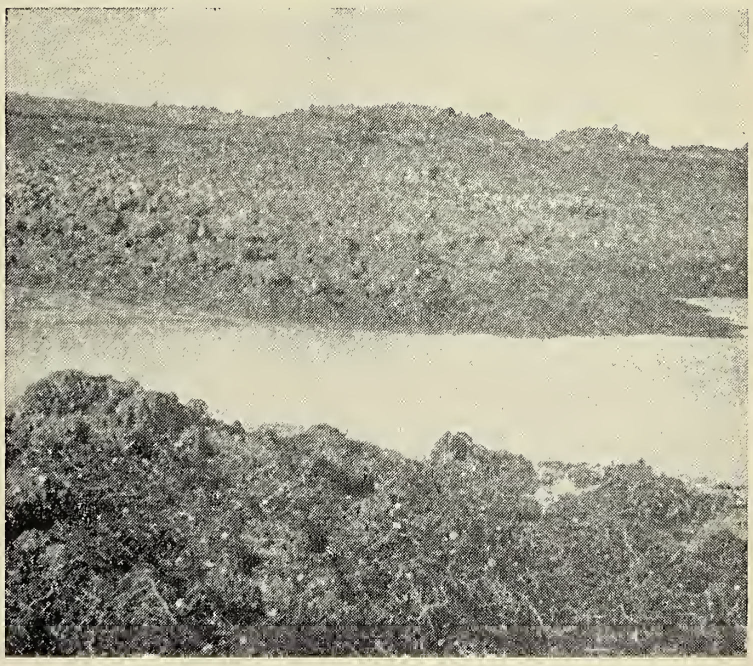

FIG. 2. Zonation on sloping scoria shore. *Chamaesipho-Saxostrea* association (white), *Corallina-Hormosira* association (grey), *Carpophyllum-Ecklonia* association (dark; bottom of slope and foreground).

Scytothamnus australis f
Apophlaea sinclairii f
Hormosira banksii o

This is the characteristic mid-tidal community of rocky shores on Rangitoto. The upper limit of this association coincides with the lower limit of the preceding association. The relative proportions of the two dominants vary with the environment. Thus, certain environmental conditions, which may differ for the two organisms, appear to be required for the optimum expression of each. As a result, in the extreme case, two consociations may be recognised.

Elminius plicatus, *Apophlaea sinclairii*, and *Scytothamnus australis* are scattered through the association. It is probable that the importance of *Apophlaea* above the upper limit of *Saxostrea* may be related to an absence of competition. *Scytothamnus* assumes local dominance in more exposed localities.

With an increase in physical exposure, *Chamaesipho brunnea* enters the association, to the extent of dominance. Its upper limit is above that of *C. columna*.

6. Hormosira banksii consociation

Hormosira banksii d
Scytothamnus australis f
Corallina officinalis f
Vermilia carinifera o
Microdictyon sp. o

The *Hormosira* community, classed under the mid-tidal formation, occupies approximately the same limits as the *Chamaesipho-Saxostrea* association of less protected shores. This plant, which is associated with physical shelter, may form a consociation on flat or broken surfaces. The community is very characteristic of scoria shores.

Vermilia carinifera may completely occupy such special substrates as isolated rocks and steep surfaces (Fig. 3).

7. Elminius-Modiolus fasciation

Elminius modestus d
Modiolus neozelanicus d
Gelidium pusillum o
Caloglossa leprieurii o
Scytothamnus australis o

This mid-tidal community occurs on the special substratum provided by wharves.

8. Enteromorpha bulbosa-Monostroma crepidinum aspect

A chlorophycean community occurs in the upper part of the levels of the formation between June and January. It is associated with physical shelter, but has no apparent relation to fresh-water drainage.

Lower Littoral Mixed Algal Formation

This formation occupies that part of the littoral which lies roughly between M.L.W.N.T. and M.L.W.S.T. It is noteworthy for the fact that all the dominants in the various communities are plants. A considerable variation in species composition is partly associated with changes in physical exposure. A basic association may, however, be recognised.

9. Corallina-Hormosira association (Fig. 2)

Corallina officinalis d
Hormosira banksii d
Codium adhaerens a
Colpomenia sinuosa a
Elminius modestus a
Cystophora torulosa a
Xiphophora chondrophylla var. *minus* a
Aeodes nitidissima a
Splachnidium rugosum f

Hormosira banksii exhibits a much-reduced thallus form as compared with the *Hormosira* plants from the upper part of its range. This appears to be associated with relative tolerance of water loss (see page 44).

Several important subordinate species appear to have ecological requirements fairly similar to those of the dominants. These are *Codium adhaerens*, *Splachnidium rugosum* (seasonal), and *Colpomenia sinuosa* (seasonal). *Elminius modestus* covers many pebbles and stones down to M.L.W.S.T.

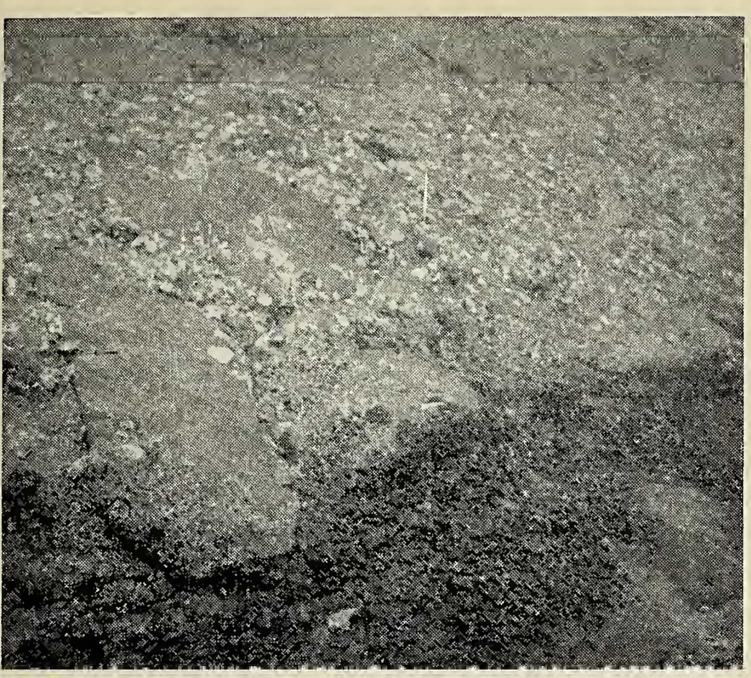

FIG. 3. Zonation on sea wall (steep, solid surface). From top: *Saxostrea glomerata*, *Vermilia carinifera*, *Codium adhaerens*.

Much variation is produced within the levels of the association by the dominance of subordinate species under special conditions. *Codium adhaerens* flourishes on steep slopes (Fig. 3) and in shade, while the seasonal *Splachnidium rugosum* dominates on some fairly exposed slopes and boulders. *Cystophora torulosa* and *Xiphophora chondrophylla* var. *minus* occur at the junction of the *Corallina-Hormosira* and brown kelp communities in fairly exposed localities, and exhibit dominance with moderate and strong exposure, respectively. *Aeodes nitidissima* assumes seasonal local dominance at similar levels in more sheltered areas.

Sublittoral Brown Kelp Formation

This formation is represented by a very consistent association, which forms the kelp belt that encircles the island.

10. Carpophyllum-Ecklonia association (Fig. 2)

Ecklonia radiata var. *richardiana*	d
Carpophyllum maschalocarpum	d
C. flexuosum	a
C. plumosum	a
Pterocladia lucida	f
P. capillacea	f
Melanthalia abscissa	f
Sargassum sinclairii	o

Carpophyllum maschalocarpum, the principal *Carpophyllum* species, is generally present in larger proportions than *Ecklonia*. In addition, *Carpophyllum flexuosum* occurs with shelter and *C. plumosum* with exposure. *Sargassum sinclarii* is scattered within the association in sheltered places. Prominent subordinates in exposed areas are *Pterocladia lucida*, *P. capillacea*, and *Melanthalia abscissa*.

11. Mytilus canaliculus-Tunicate fasciation

This community occurs on vertical and shaded surfaces, which are unsuitable for the general establishment of the large phaeophyceans. Scattered specimens of *Ecklonia* and *Tethya fissurata* occur in the community.

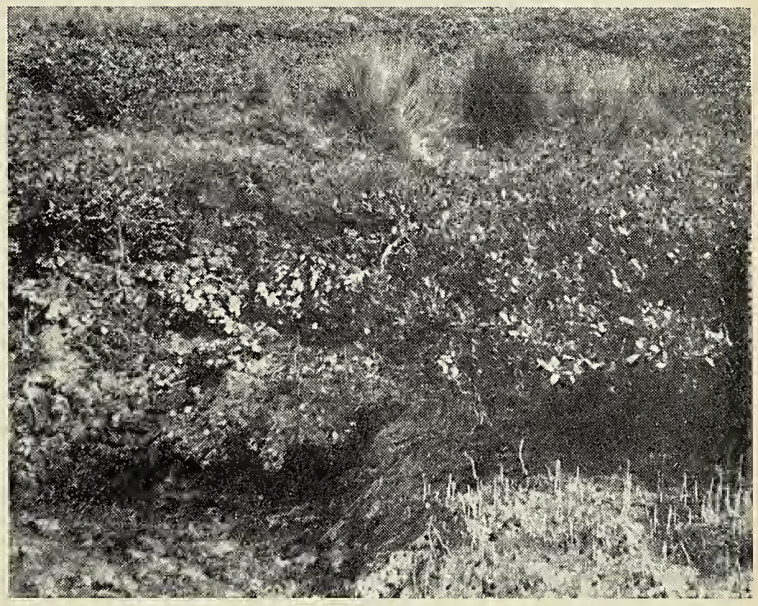

FIG. 4. Communities of Scoria Flat Inlet. *Salicornia-Stipa* associes (above), *Avicennia officinalis* consocies (showing pneumatophores), *Saxostrea glomerata* on vertical rock surfaces, and *Hormosira banksii* where there is sediment.

SERAL COMMUNITIES (Fig. 4)

The maximum development of seral communities takes place on sedimentary substrata in sheltered places. There is a zonation of several communities, each dominated by angiosperms. In each case, aggradation, characteristic of seral communities, occurs.

1. Salicornia-Stipa associes

Salicornia australis	d
Stipa teretifolia	d
Rhizoclonium hookeri	f

Melarhaphe oliveri f
Suaeda maritima o
Triglochin striata var. *filifolium* r

This is principally a community of about M.H.W.S.T. In the shelter of the dominant angiosperms is a *Rhizoclonium hookeri* socies.

2. Avicennia officinalis consocies

This is a mid-tidal community. Although the vertical range within which mangrove seedlings will develop is narrow, a mature plant occupies a wide vertical range by virtue of its size. A community of *Rhizoclonium hookeri*, *Catenella nipae*, *Caloglossa leprieurii*, and sediment-fixing Myxophyceae occurs on the pneumatophores. In some areas, *Hormosira banksii* is attached to the pneumatophores, and to scoria where this is present. *Gracilaria secundata* f. *pseudoflagellifera* appears to be free-living on the surface of the mud.

3. Zostera nana consocies

This is the community of the lowest littoral and the upper sublittoral.

LEVELLING SURVEY

A numerical account of distribution was provided by means of a levelling survey. The species were treated individually because of the wide variety of vertical and horizontal ranges which produces the observed complexity of community groupings.

The upper and lower limits of the intertidal organisms were determined as relative to tide levels, both for the elucidation of causal factors and for correlation with similar work elsewhere. There being no bench marks on the island, all levellings were referred to marks established above E.H.W.S.T., these marks in turn being tied to E.L.W.S.T. as determined for the island (see "Tidal Factors"). The levels given below are based on E.L.W.S.T. as 0.00 feet.

Relation of Communities to Levelling (Figs. 5, 6)

The levels for an apparently normal zonation confirm the observed communities. There is a definite tendency for the majority of the upper and lower limits of species to occur in the vicinity of the apparent limits of formations and communities.

It is also possible to postulate critical levels at which significant changes in species composition occur. Five such levels were recognised on Rangitoto. The lowest critical level on the shore was placed at 1.50 feet, being the average of the seven upper limits and eight lower limits of species which were located between the levels 1.00 feet and 2.00 feet above E.L.W.S.T. Others were placed at 3.75 feet (five upper and three lower limits between 3.50 feet and 4.00 feet); at 8.00 feet (five upper and four lower limits between 7.50 feet and 8.50 feet); at 9.30 feet (seven upper and five lower limits between 9.00 feet and 9.75 feet); and at 11.00 feet (nine upper and three lower limits between 10.50 feet and 11.50 feet).

The numerical basis of these levels (to the nearest 0.5 foot) is shown in Figure 6. The principal levels of change in species composition are clearly in the vicinity of 1.5, 3.5, 9.5, and 11.0 feet.

FACTORS INVOLVED

Tidal Factors

Tidal Information. The tides at Auckland are of the normal semidiurnal type, with a diurnal inequality. Tidal measurements are made at Queen's Wharf by the Auckland Harbour Board's tide instrument. The zero for these measurements is E.L.W.S.T., taken as 3 feet above the Auckland Dock Sill. The Admiralty Datum, upon which the tidal data in the New Zealand Nautical Almanac are based, is 3.5 feet above the Dock Sill.

Tidal Behaviour at Rangitoto. Since it was intended to use the tide charts prepared by the Auckland tide machine in the calculation of submergence and emergence, and also because the correlation of littoral levelling with similar work elsewhere had of necessity to be through tide levels, a determination of

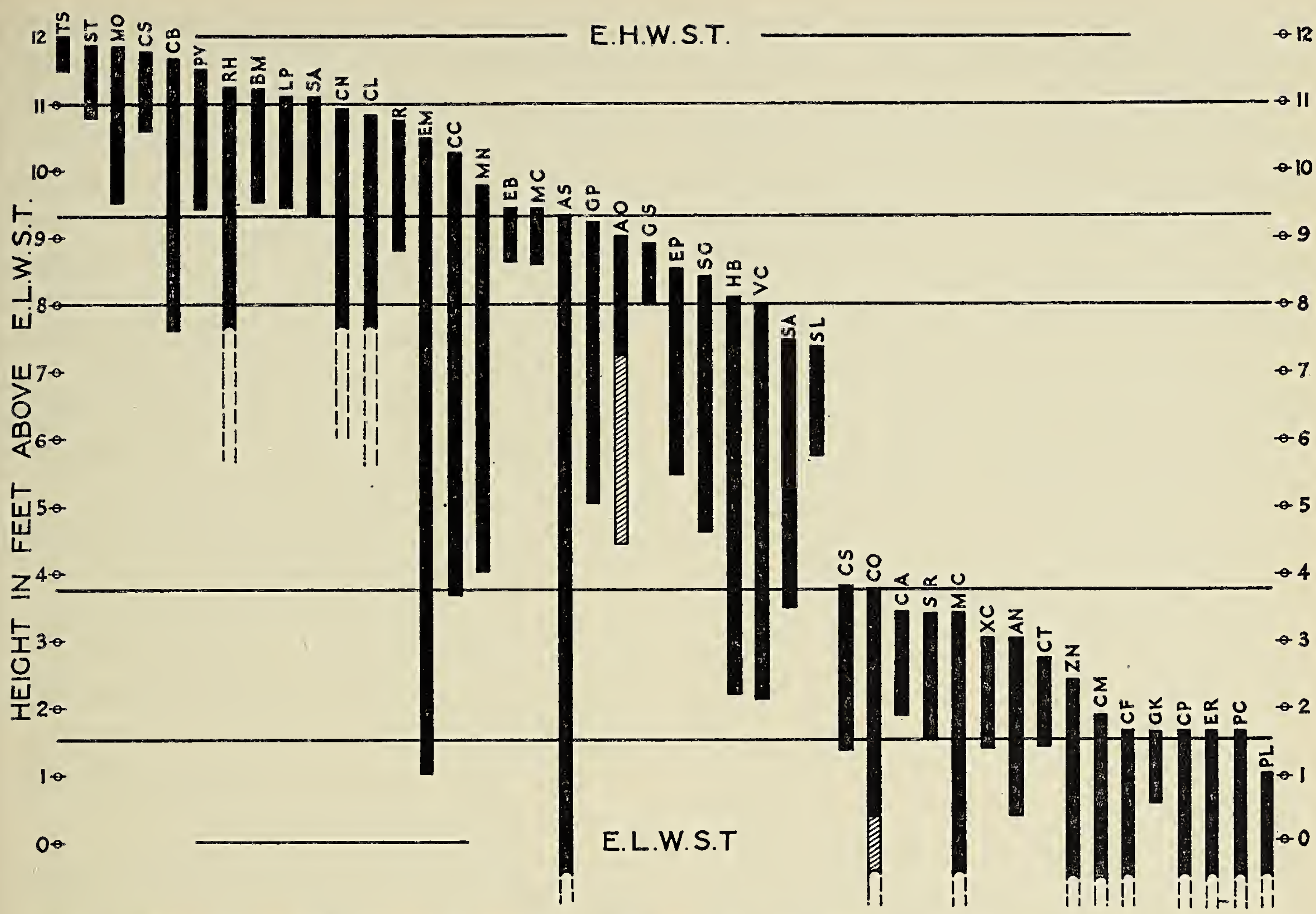

FIG. 5. Vertical ranges of important organisms. Significance of key letters in figure (reading from left to right):

TS	Triglochin striatum	MN	Modiolus neozelanicus	CA	Codium adhaerens
ST	Stipa teretifolia	EB	Enteromorpha bulbosa	SR	Splachnidium rugosum
MO	Melarhaphe oliveri	MC	Monostroma crepidinum	MC	Mytilus canaliculus
CS	Calothrix scopulorum	AS	Apophlaea sinclairii	XC	Xiphophora chondrophylla
CB	Chamaesipho brunnea	GP	Gelidium pusillum	AN	Aeodes nitidissima
PV	Placoma vesiculosa	AO	Avicennia officinalis	CT	Cystophora torulosa
RH	Rhizoclonium hookeri	GS	Gracilaria secundata	ZN	Zostera nana
BM	Bostrychia mixta	EP	Elminius plicatus	CM	Carpophyllum maschalocarpum
LP	Lichina pygmaea	SG	Saxostrea glomerata	CF	Carpophyllum flexuosum
SA	Salicornia australis	HB	Hormosira banksii	GK	Glossophora kunthii
CN	Catenella nipae	VC	Vermilia carinifera	CP	Carpophyllum plumosum
CL	Caloglossa leprieurii	SA	Scytothamnus australis	ER	Ecklonia radiata
R	Ralfsia sp.	SL	Scytosiphon lomentaria	PC	Pterocladia capillacea
EM	Elminius modestus	CS	Colpomenia sinuosa	PL	Pterocladia lucida
CC	Chamaesipho columna	CO	Corallina officinalis		

tidal behaviour relative to that at Auckland was undertaken at Rangitoto.

When possible, days of dead calm were chosen for tidal readings. The principal station for tidal measurements was the bridge at Scoria Flat Inlet, on the southwest shore of the island. The times, and heights relative to the centre point of the bridge deck, of high water under the bridge were accurately determined on a number of days. No low-water readings were possible, inasmuch as the Inlet dries out. A reasonable correlation with the times and heights of the same tides at Auckland was obtained. The vertical distance of E.H.W.S.T. below the bridge deck was determined, and E.L.W.S.T. placed 12.0 feet lower, as at Auckland. This was justified by observations of the tidal ranges elsewhere on the island. For this purpose tide poles were established and the times and heights of high and low water accurately determined. The times of high and low water were almost identical with those at Auckland, but there seems to be a slight local variation in the tide range at each place as compared with that at Auckland. Full-tide curves made at Rangitoto Wharf (south coast) show no irregularities.

For the comparison of the levellings at the various places with the levellings at Scoria Flat, E.L.W.S.T. was approximately determined on the basis of the tide readings made at each place, equality being assumed between the Auckland and the local tides.

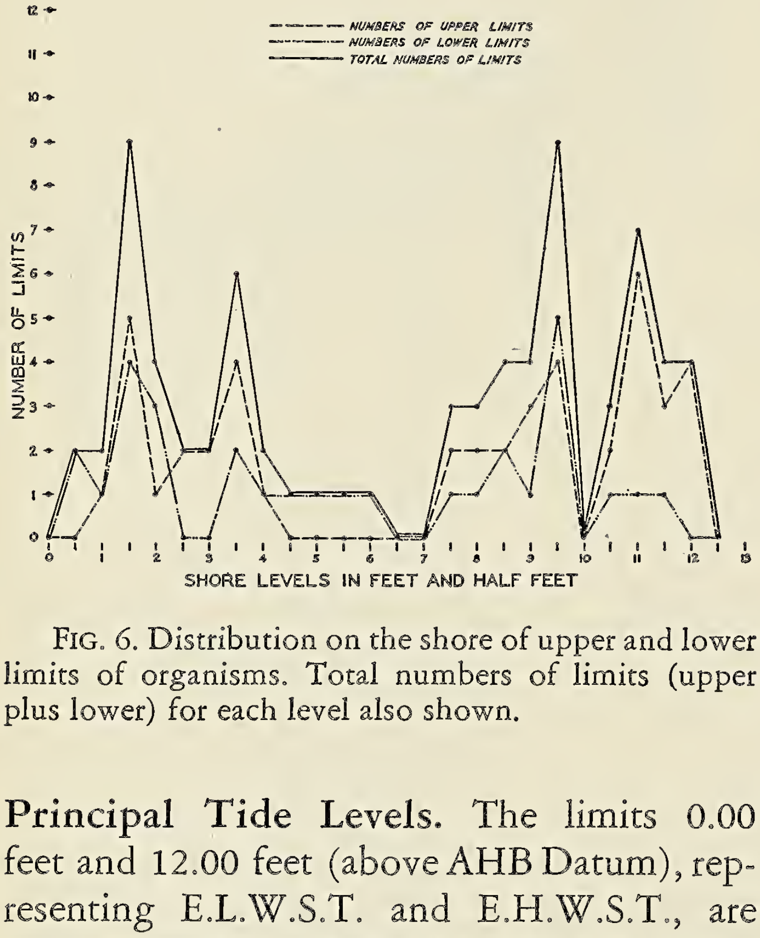

FIG. 6. Distribution on the shore of upper and lower limits of organisms. Total numbers of limits (upper plus lower) for each level also shown.

Principal Tide Levels. The limits 0.00 feet and 12.00 feet (above AHB Datum), representing E.L.W.S.T. and E.H.W.S.T., are never normally exceeded by tidal fall or rise.

Certain levels for Queen's Wharf for 1947 were calculated from the Nautical Almanac predictions (in each case the calculated level is followed by the average of the actual recorded tides at Queen's Wharf for the 3 years 1945–1947, by courtesy of Miss U. V. Dellow). These levels are: E.H.W.S.T., 11.90 feet (11.95 feet); M.H.W.S.T., 11.01 feet (11.41 feet); M.H.W.N.T., 9.22 feet (9.28 feet); M.L.W.N.T., 3.31 feet (3.29 feet); M.L.W.S.T., 1.36 feet (1.12 feet); E.L.W.S.T., 0.60 foot (0.60 foot).

The lowest high water recorded is extreme (low) high water of neap tides (E.(L.)H.W.N.T.), and the highest low water is extreme (high) low water of neap tides (E.(H.)L.W.N.T.). All levels between these (8.40 feet [8.88 feet] and 4.00 feet [3.96 feet], respectively) are subjected to alternating submergence and emergence twice in every 24 hours. For all levels above E.(L.)H.W.N.T. there is, therefore, a varying amount of continuous emergence; and similarly, for all levels below E.(H.)L.W.N.T., a varying amount of continuous submergence.

The correlation of tidal information with critical levels may be given as:

The critical level 1.5 feet is just above M.L.W.S.T.

The critical level 11.0 feet is just below M.H.W.S.T.

The critical level 3.75 feet lies between M.L.W.N.T. and E.(H.)L.W.N.T.

The critical level 9.3 feet is approximately M.H.W.N.T.

The critical level 8.0 feet is below E.(L.)H.W.N.T.

Significance of Tide Levels. Some of these levels appear to represent thresholds. For example, E.(L.)H.W.N.T. is the highest level of regular, semidiurnal, alternating submergence and emergence, while E.(H.)L.W.N.T. is the lowest level regularly uncovered by the tide. To determine the significance of such levels, the tidal factor was analysed with respect to submergence-emergence relations and to continuous emergence and submergence.

The submergence-emergence behaviour of the tides at Auckland was determined from the tide charts prepared by the instrument at Queen's Wharf. These charts are graphs of sea level against time. Calculations were made of the relative submergence and emergence of the different levels between the extreme limits of inundation, expressed in terms of the percentage of the total time considered during which each 1-foot level was not submerged. This was done for a tidal period of 360 hours (spring to spring) (Fig. 7A). A better average is obtained over a lunar month, or better, a lunar year (Fig. 7B).

The probable significance of relative submergence and emergence lies in the rate of increase of percentage emergence with height on the littoral (Fig. 7). This rate of increase rises to two peaks, occurring between 3.0 feet and 4.0 feet and between 9.0 feet and 10.0 feet. These sharp changes in the rate of increase might be the basis of thresholds in the vicinity of M.L.W.N.T. (3.31 feet) and of M.H.W.N.T. (9.22 feet).

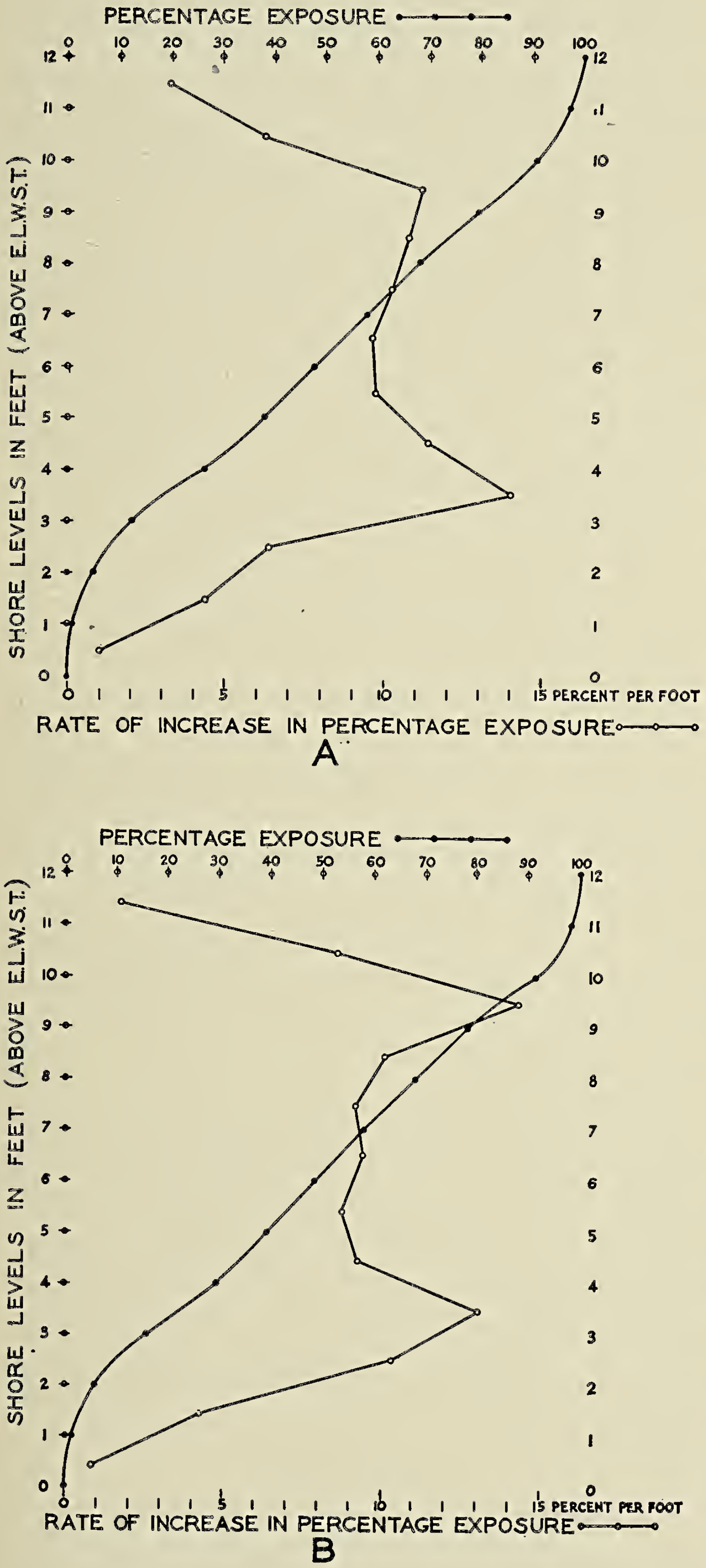

FIG. 7. Percentage emergence ("percentage exposure") for each foot between E.L.W.S.T. and E.H.W.S.T. A, for one tidal period (360 hours), Jan., 1947; B, for one lunar year (1945) (A. E. Beveridge). Rate of increase in percentage emergence ("percentage exposure") also shown in each case.

Calculations were made (from the Nautical Almanac predictions) of the periods of continuous emergence undergone by each level above E.(L.)H.W.N.T. in 1947, and of the periods of continuous submergence undergone by each level below E.(H.)L.W.N.T.

The maximum period appears to be important in each case. In the case of emergence, it is 1 day at 8.5 feet (through missing a single tide). It then rises fairly steadily to 9 days at 10.0 feet. There is a fairly sharp rise to 23 days at 10.5 feet and to 43 days at 11.0 feet. A great increase in the maximum period of emergence then occurs, the time being 132 days at 11.5 feet. Above M.H.W.S.T., a condition of permanent emergence is swiftly attained. Fairly similar behaviour is associated with the periods of continuous submergence. Here a fairly steady rise to 25 days at 1.5 feet is followed by a sharp rise to 131 days at 1.0 foot. The 0.5 foot level is permanently submerged.

The important point would appear to be the meaning given to the mean limits of spring tides (defined under "Terminology" as the limits of the littoral) by the great rises in the maximum periods of continuous emergence and submergence at M.H.W.S.T. and M.L.W.S.T., respectively. Here again the levels appear to be thresholds.

The relatively large increase in maximum continuous emergence between 10.0 feet and 11.0 feet may control the upper limits of *Chamaesipho columna* (10.3 feet) and *Elminius modestus* (10.5 feet).

Behaviour of Hormosira banksii. In each of the above cases, it would seem that phenomena associated with tidal inundation provide physiological limits to the vertical distribution of littoral species. Each change in environmental conditions is a barrier which cannot be surmounted by certain species, either in establishment as young plants or animals, or in development.

Reaction to the causal factors is shown in one way by *Hormosira banksii*. This alga plays a prominent part in the littoral ecology of Rangitoto because its vertical range is from M.L.W.S.T. to E.(L.)H.W.N.T. The young plant, or "button," is found throughout this range and up to 1 foot above the upper limit.

Mature plants show considerable variability. The size of the plants, with regard to the size of the receptacles (and, to a lesser degree, to the number thereof), is proportional to their height above E.L.W.S.T. (The average diameter of the receptacles ranged from 1.50 centimetres in plants near the upper limit of the species to 0.75 centimetre in plants near the lower limit.) Further, the thickness of the wall of the receptacle was found to be inversely proportional to the diameter. (The average thickness of the walls ranged from 0.11 centimetre in plants near the upper limit of the species to 0.14 centimetre in plants near the lower limit.) Finally, the rate of water loss from plants during emergence was found to be inversely proportional to their height on the shore (Fig. 8). On the basis of these measurements, the rate of water loss is, therefore, inversely proportional to the volume of the water-filled, hollow interiors of the receptacles. In support of this, determinations of the above quantities were also made with samples of a special, large form of *Hormosira* (D in Fig. 8), which is found back from the shore in those low scoria areas where tidal seepage occurs. The receptacles of these plants were found to have an average diameter of 1.70 centimetres and an average wall-thickness of 0.10 centimetre, and their rate of water loss was the lowest recorded.

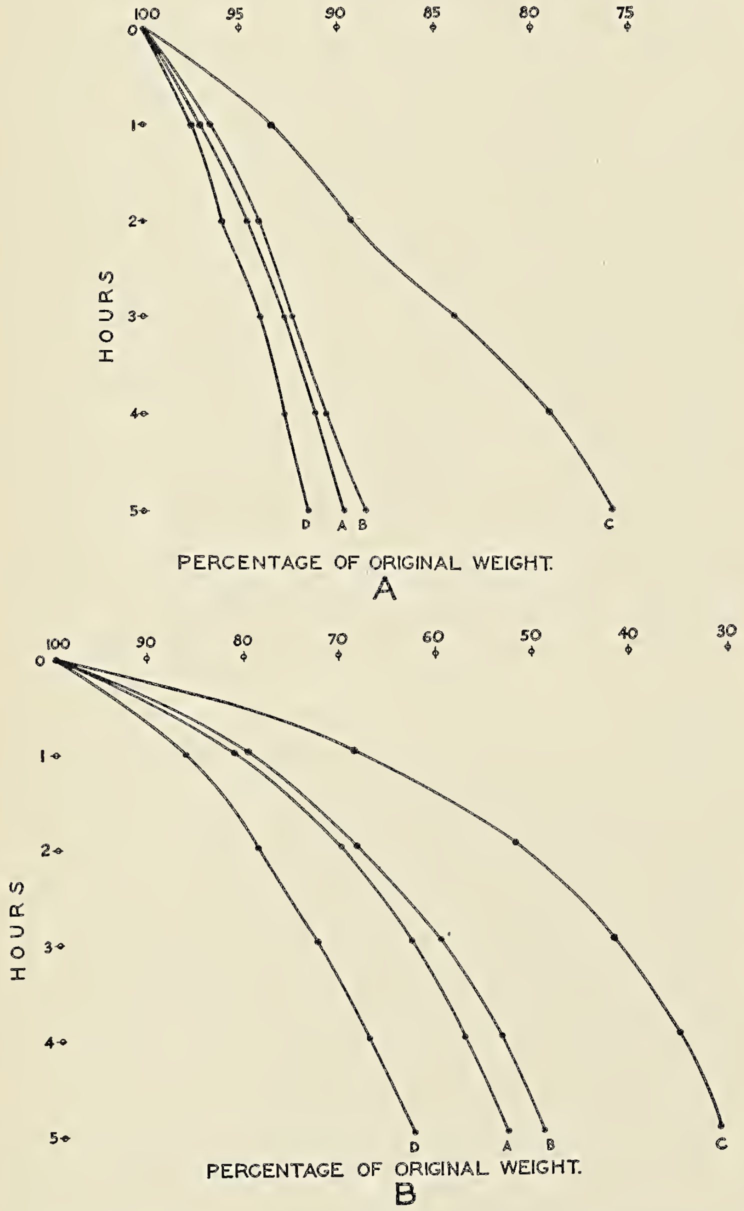

FIG. 8. Loss of weight of *Hormosira banksii* thalli during emergence ("exposure"). Mean percentage loss of weight per hour (under identical conditions) of: A, numbers of plants of *Hormosira banksii* from top of range; B, main *Hormosira* consociation; C, *Corallina-Hormosira* association; and D, of special form (see text). 8A, in laboratory; 8B, in sunlight.

It seems possible, therefore, that the relatively large vertical range of *Hormosira banksii* depends on a considerable tolerance of differences in submergence-emergence relations in the "button" stage, together with morphological variation in the adult in relation to the degree of desiccation undergone at different levels.

Other Factors

In the foregoing section, the fundamental nature of zonation as a function of the tidal factors has been discussed. The final pattern of distribution may be considered as the product of the reaction of the basic vertical zonation with a set of variables.

The object of the work classed under this section was the determination of these variables, partly from detectable variations in the vertical levelling and partly in more empirical ways.

The factors sought may be classified roughly into two groups: the modifying factors, evidenced by variations in vertical distribution; and the presence-or-absence factors, as manifested by differences in transect composition.

Modifying Factors. Most of the observed variations in vertical distribution took the form of raised upper limits. There were few cases of lowering of lower limits. The general basis of the factors inducing the former may be the prevention of normal desiccation, and of the latter, the lessening of normal submergence. The upper limit of *Hormosira banksii* is raised by as much as 1.0 foot by prevention of run-off on fairly flat scoria shores and in mangrove swamps. Similarly, seepage induced by the pervious nature of the scoria substratum results in the occurrence of *Zostera nana*, *Aeodes nitidissima*, the kelps, and species of *Pterocladia* in the lower littoral at much higher levels than those determined by the tidal factors.

At exposed points, the upper limits of some species at the upper boundary of the littoral may be raised to considerable heights through the influence of spray, while aeration may lower the lower limits of some species at the lower boundary of the littoral. *Melarhaphe oliveri*, whose normal upper limit is E.H.W.S.T., is found on the northern coasts on top of the cliffs, 10.0 feet or more above theoretical E.H.W.S.T. In exposed places, *Chamaesipho columna* may be found dominant down to E.L.W.S.T., more than 2 feet below its lower limit, on less exposed shores. This may be due to wave-induced aeration or to increased light because of the clearer water of the outer shores.

The micro-climates, provided by the topography of the scoria or by actual vegetation, present another case of the raising of upper limits by the reduction of exposure-induced desiccation. Within clefts in the upper littoral, where the relative humidity was determined by rough wet-and-dry bulb tests to be about 25 per cent higher than in the open, the upper limits of *Catenella nipae* and *Caloglossa leprieurii* are raised by 0.7 foot. Under *Hormosira banksii* thalli, similar tests show the humidity to be about 30 per cent higher than in the open. In the *Hormosira* consociation, the subordinate *Corallina officinalis* occurs up to 3.0 feet above its normal upper limit, and *Microdictyon* sp. nearly as much.

In other cases, direct protection from insolation appears responsible for raising the upper limits of species, e.g., *Codium adhaerens* (raised 1.5 feet) and *Ecklonia radiata* var. *richardiana* (0.75 foot).

Presence-or-absence Factors. Of the factors controlling the presence or absence of species at one point, the one best exhibited at Rangitoto is relative physical exposure. The geography of the island provides a wide range of conditions. It would appear that physical exposure inhibits the establishment of some species, while sheltered conditions, and especially the encouragement of sedimentation, act against other species.

Xiphophora chondrophylla var. *minus*, *Carpophyllum plumosum*, *Pterocladia lucida*, *P. capillacea*, *Glossophora kunthii*, and *Chamaesipho brunnea* occur only under conditions of exposure, while *Hormosira banksii* occurs only in shelter. *Cystophora torulosa*, *Scytothamnus australis*, and *Splachnidium rugosum* are dominant only in exposed places. Conversely, *Saxostrea glomerata* thins out with exposure. Most of the other dominants, however, appear indifferent to the degree of physical exposure. *Corallina officinalis* is reduced to its basal portion by exposure.

The nature of the substratum affects the presence or absence of species. The sedimentation induced by shelter results in fasciations and seral communities. In the case of the predominant rocky shores, the variable nature of the basalt is often the indirect basis of other environmental variations. The scoria shores, the broken surfaces of which provide pockets of shelter, are likely to show a mosaic of climax and seral communities.

General texture may be involved (Fig. 3). An unbroken surface favours *Saxostrea glomerata*. At lower levels, an unbroken surface favours *Codium adhaerens* and a broken one the *Corallina-Hormosira* association. The *Carpophyllum-Ecklonia* association requires a solid substrate for the attachment of the large dominants. Boulders on an exposed shore appear to favour a zonation of *Scytothamnus australis*, *Splachnidium rugosum*, and *Glossophora kunthii*.

Physical exposure appears to be reduced by a flat shore so that a habitat, such as the top of a lava flow, results in the development of the *Hormosira banksii* consociation, while *Saxostrea glomerata* occurs on slopes. Further, *Codium adhaerens* tends to dominate on vertical surfaces (Fig. 3), while *Corallina officinalis* and *Hormosira banksii* are best developed on flatter shores. Again, vertical surfaces in the upper sublittoral bear *Mytilus canaliculus*, tunicates, and some *Ecklonia* in place of the usual *Carpophyllum-Ecklonia* association.

Finally, differences in shade tolerance produce some variations. *Carpophyllum maschalocarpum* is reduced in shade, while *Ecklonia* is more tolerant. In the shade of the kelps, *Corallina officinalis* is reduced to its basal filaments, while *Aeodes nitidissima* is eliminated. *Codium adhaerens* is favoured by shade to the extent of frequent dominance in the levels of the *Corallina-Hormosira* association on the southern sides of rocks. It is probable that the discoloration of sheltered waters by sediment in suspension, with subsequent light reduction, operates in excluding at least some of the species associated with physical exposure.

Tidally Controlled Variations. It must be noted that not only seasonal climatic conditions but also seasonal variations in tidal behaviour may be responsible for the fluctuations of some species. Thus the occurrence in the autumn of the maximum periods of continuous submergence of the lower littoral levels for the year may have been responsible for the establishment of *Colpomenia sinuosa* and the disappearance of *Splachnidium rugosum* in that season. Similarly, the spring maximum of the *Enteromorpha bulbosa–Monostroma crepidinum* aspect might be associated with the fact that the maximum periods for the year of continuous emergence in the upper littoral occurred at that time.

SUMMARY

An attempt has been made to classify the communities of inter-tidal plants and animals at Rangitoto Island. The climax communities appear to fit into the general, basic, rocky-shore zonation for New Zealand.

The causal factors in vertical zonation at Rangitoto, namely, those determining the upper and lower limits of species, have been related to tidal phenomena. Attention has been given to the behaviour relative to tide levels of *Hormosira banksii*. The variables, which produce variations in the vertical limits of species and in species composition, have been sought in environmental factors other than tidal.

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A New Atherinid Fish of the Genus *Iso* from the Hawaiian Islands[1]

William A. Gosline[2]

Two species of atherinid fishes are known from the Hawaiian Islands. One is the iao (*Pranesus insularum*[3]) used as bait by the tuna fishermen and known to occur in numbers at least from Oahu through the leeward Hawaiian Islands to Midway. The other species (*Iso hawaiiensis*) is here described.

The two Hawaiian atherinids may be distinguished readily, for *Iso* has a deep, sharply edged abdomen (Fig. 1*b*) which will separate it from not only the iao, but also from any of the other small silvery fishes in the region.

Iso hawaiiensis new species

Fig. 1*a*, *b*

HOLOTYPE: U. S. National Museum No. 152759, 28 mm. in standard length, taken in a poison station October 3, 1950, by Gosline and class over sand off a rocky point ½ mile west of Makapuu Point, Oahu, Territory of Hawaii. This is normally an area of heavy surf.

PARATYPES: University of Hawaii No. 957, two specimens 20.0 mm. and 18.5 mm. in standard length, taken with the holotype.

Body very compressed, maximum width at shoulder contained 7.1 to 7.4 times in standard length. Breast forming keel, sharp-edged in cross section (Fig. 1*b*), convex in longitudinal outline. Dorsal profile gently and more or less evenly convex from above eye to second dorsal origin. Snout bluntly rounded. Body tapering between second dorsal and anal. Body depth 3.4–3.7, head length 3.6–4.3 in standard length.

Eye diameter 2.1–2.7 in head, somewhat greater (in these small specimens) than snout or interorbital width. Mouth very oblique, forming angle of about 60 degrees with horizontal axis. Premaxillaries not protractile, attached to head by frenum on the middorsal line, not expanded posteriorly, and not bound down to mandibles by a membrane between the jaws. Maxillaries toothless, slightly concave in front. Lower jaw deep and bluntly rounded, slightly included within upper when the mouth is closed. [I am unable to discover any teeth even in the largest of these three small specimens.] Lips covered with series of soft, tooth-shaped papillae. Membranes stretched across mouth on inside of each jaw, lower membrane larger. Gill openings wide, membranes free. Gill rakers long, about 12 in number (counted in the holotype only and without extracting). Cleft behind first gill arch wide, behind second moderate, behind third restricted, and behind fourth absent. Branchiostegal rays 5–5 in holotype.

Dorsals IV or V, I 16. First dorsal originates very slightly anterior to point midway between pelvic and anal origins, its spines all very slender and of approximately equal length. Second dorsal originates about twice as far from caudal base as from tip of snout, above base of eighth anal ray. Spine of second dorsal about 0.5 the length of the first soft ray, preceded by fleshy projection from back. Dorsal and anal highest forward, tapering sharply to middle of fin, more gradually thereafter. Pectorals short and rounded, origin of uppermost ray above most posterior point on opercle, nearer dorsal outline than to upper edge of silvery lateral band.

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[1] Contribution No. 15, Hawaii Marine Laboratory.

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[3] For the generic allocation of this species see Schultz, 1948: 23.

Distance from snout to ventrals contained about 1.6 times in ventral–caudal distance. Vent near but not quite at the origin of the anal, preceded on the ventral midline by about four pairs of body scales.

Scales cycloid, ovoid on sides, absent from head and front of body. About 38 scales or scale pockets in a longitudinal series on the holotype; scales lacking on paratypes.

Color in alcohol whitish except for silvery eye, cheek, occipital region, and lateral band. Lateral band broadest about under origin of second dorsal, slightly less than an eye diameter in width (in these small specimens). Silvery lateral band disappears about midway along caudal peduncle, reappearing again as a rather indefinite, irregular silvery spot just before caudal base. In life this fish is brilliantly silvery. [It is my impression that the silvery reflections came from the whole fish and not merely from the regions that retain the silver coloration in alcohol.]

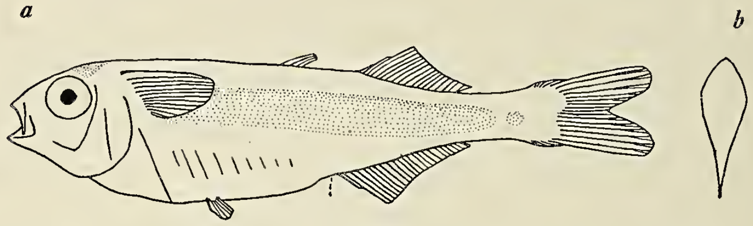

FIG. 1. Holotype of *Iso hawaiiensis*. *a*, Lateral aspect; *b*, cross section through the deepest part of body.

TABLE 1

MEASUREMENTS* AND COUNTS ON *Iso hawaiiensis*

CHARACTER	HOLOTYPE	PARATYPES	
Total length	34.2 mm.	24.0 mm.	22.5 mm.
Standard length	28.0 mm.	20.0 mm.	18.5 mm.
Snout to first dorsal	538	490	508
Snout to second dorsal	693	661	703
Length of first dorsal base	54	60	59
Between dorsals	143	110	97
Length of second dorsal base	193	235	249
Snout to ventrals	438	415	379
Snout to anus	636	570	535
Anus to anal	36	45	49
Length of anal base	239	275	276
Length of caudal peduncle	175	160	168
Depth of caudal peduncle	86	90	97
Depth of body	293	295	270
Width of body	136	140	141
Head length	275	235	243
Upper jaw length	104	110	114
Snout length	93	80	86
Eye diameter	100	105	114
Width of interorbital	86	90	103
Length of first dorsal spine	82	75	81
Length of longest anal ray	118	105	108
Length of pectoral	168	165	178
Length of ventral	121	115	108
Greatest width of silvery band	79	85	76
Number of pectoral rays	13	12	13
Number of caudal rays	I-15-I	I-15-I	I-15-I
Number of first dorsal spines	IV	V	V
Number of second dorsal rays	I, 16	I, 16	I, 16
Number of anal rays	I, 22	I, 20	I, 24

* All measurements, except standard and total length, given in thousandths of the standard length.

Iso hawaiiensis belongs to the small and aberrant atherine subfamily Notocheirinae (Schultz, 1950: 150). Schultz (1948: 5) divides this subfamily into three genera. Of these *Notocheirus*, based on two specimens from Chile, is certainly distinct. However, Schultz's other two genera—*Iso* and *Tropidostethops*—are so closely related that I can find no morphological or philosophical grounds for separating them. The only distinguishing character Schultz (1948) gives is the configuration of the silvery lateral band quoted in section 1 of the key given below. This difference hardly seems of generic value; if other more significant differences exist, they are not stated in the literature. Furthermore, Jordan and Hubbs, in an earlier revision of the Atherinidae (1919: 47), have compared the genotypes of *Iso* and *Tropidostethops* and consider them to be congeneric. This is particularly significant as Jordan and Hubbs split the atherine genera rather finely (they divide 149 species and subspecies between 38 genera, giving an average of 3.9 species and subspecies per genus). Smith (1949: 324), writing subsequently to Schultz, also fails (by inference) to recognize these two genera.

If both genera are recognized, *Iso* becomes monotypic, and *Tropidostethops* would contain four known species. Even the geographic distribution of such genera would not be significant. *Iso* would be limited to Japan, whereas *Tropidostethops* would have representatives in southern Africa, India, Australia, and now Hawaii.

Finally, Schultz's fine discrimination between these two atherinid genera is not consistent with his own broad interpretation of genera in certain other groups, e.g., in eels (Schultz and Woods, 1949).

For the above reasons I consider *Tropidostethops*, to which *Iso hawaiiensis* would be assigned if *Tropidostethops* were considered valid, a synonym of *Iso*.

In view of the addition of *Iso hawaiiensis* and of the redescription of *Iso natalensis* by Smith (1935: 178, pl. 19, fig. c), Herre's (1944: 47) key to the species of this genus stands in need of revision. It may be rewritten as follows:

1. "Silvery lateral band continuous and not interrupted. (Japan)"[4] .... *Iso flos-maris*
   "Silvery lateral band fading and interrupted or narrowly constricted on caudal peduncle, then continuing and expanding, ending in a prominent silvery area"[4] 2
2. Maxillary with external teeth. Scales in a longitudinal series 40–44. (India) .... *Iso flos-indicus*
   Maxillary without external teeth....... 3
3. Scales in a longitudinal series about 38; teeth apparently absent. (Hawaii).. .... *Iso hawaiiensis*
   Scales in a longitudinal series more than 45; teeth present............... 4
4. Depth 3.5–4.0 in standard length; scales in a longitudinal series about 49. (Australia).......... *Iso rhothophilus*
   Depth 3.2–3.4 in standard length; scales in a longitudinal series about 74. (South Africa)........ *Iso natalensis*

With the addition of *Notocheirus hubbsi* to the above species, the distribution of the Notocheirinae—South Africa, India, Australia, Hawaii, and Chile—becomes unique, so far as I am aware, among fish groups.

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[4] Quoted from Schultz (1948: 6).

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Germination of Seed of Koa Haole (*Leucaena glauca* (L.) Benth.)[1]

ERNEST K. AKAMINE[2]

THE DATA IN THIS PAPER attest to the accuracy of a statement by the author to the effect that untreated seed of koa haole (*Leucaena glauca* (L.) Benth.) may require several years to germinate under natural conditions (Akamine, 1942). The question has been raised as to the actual time required for the seed to germinate; consequently, germination tests were conducted in soil flats in the greenhouse. Each test lot consisted of 1,000 seeds, with emergence of seedlings as the criterion of germination. Weekly germination counts were made and sprouted seedlings were removed from the flats. The soil was kept moist throughout the germination period, and optimum conditions for germination were maintained. Seeds that were held for a period of time prior to germination were stored at room temperature.

Results, shown in Figure 1, indicate that 1-month-old seed of one lot germinated more than 90 per cent in 1 year, whereas seed of similar age, but of another lot, germinated only approximately 20 per cent in nearly 4 years. Germination of the 2-month-old seed of one lot differed from that of another lot, as did the germination of the 10-month-old seed, although not to the extent of the other age groups.

Delayed germination in koa haole seed is caused by an impervious seedcoat ("hard" seed) (Akamine, 1942). The differences in germination of the various seed lots were found to be related to the differences in the percentage of hard seeds, i.e., the higher the percentage of hard seeds, the lower the rate of germination. These seeds, recovered from the slow germinating lots at the end of the experiment, germinated rapidly when scarified with sulfuric acid or nicked with a knife. The results indicate that the least dormant seed requires about 1 year for maximum germination, but that the more dormant the

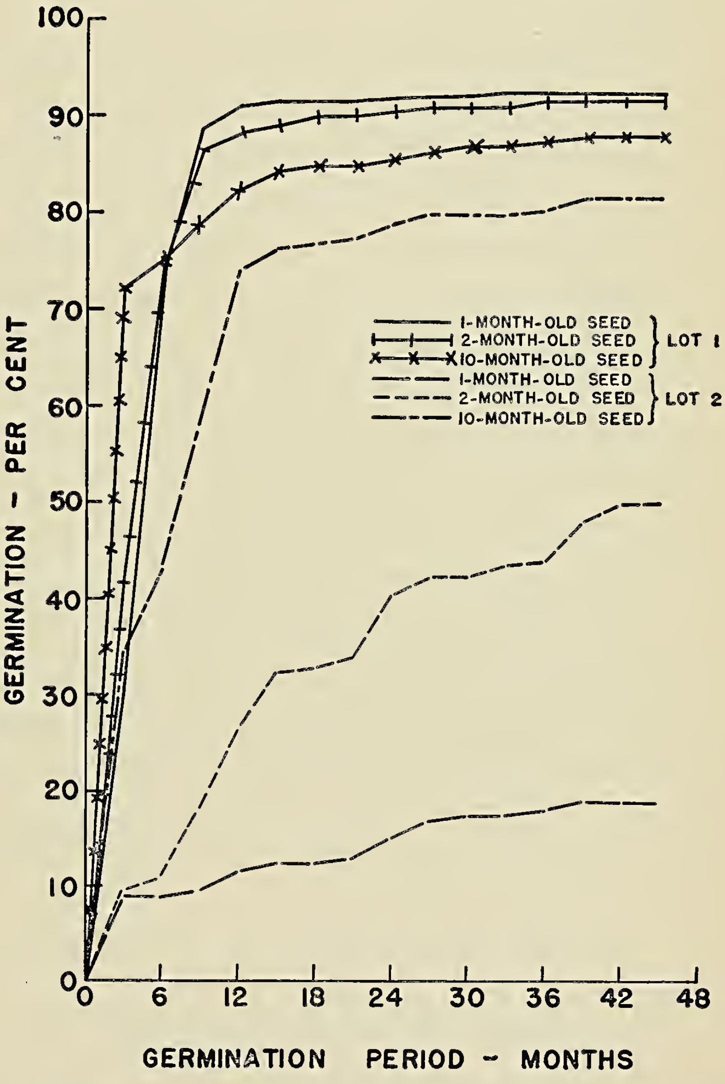

FIG. 1. Germination of koa haole seeds of different ages and lots.

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[1] Published with the approval of the Director of the University of Hawaii Agricultural Experiment Station as Technical Paper 215. Manuscript received December 15, 1950.

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TABLE 1

EFFECT OF AGE ON GERMINATION OF KOA HAOLE SEED

GERMINATION PERIOD (MONTHS)	PERCENTAGE GERMINATION OF SEEDS PLANTED							
	3 DAYS AFTER HARVEST	1 MONTH AFTER HARVEST	2 MONTHS AFTER HARVEST	4 MONTHS AFTER HARVEST	6 MONTHS AFTER HARVEST	8 MONTHS AFTER HARVEST	10 MONTHS AFTER HARVEST	12 MONTHS AFTER HARVEST
4	50.4	50.2	47.5	79.2	80.5	74.6	73.5	44.0
8	80.1	86.2	84.1	89.4	86.6	77.3	76.9	73.4
12	89.9	91.2	88.6	90.5	88.3	78.1	82.5	83.0
16	90.4	91.4	89.4	91.3	89.8	80.8	84.6	84.6
20	90.9	91.6	90.0	92.2	90.7	81.2	85.0	85.0
24	91.4	92.0	90.7	92.6	90.9	81.3	85.7	86.4
28	91.5	92.1	90.9	92.6	91.6	82.5	86.8	87.2
32	91.6	92.2	91.1	93.0	92.0	83.1	86.9	87.4
36	92.0	92.6	91.4	93.1	92.0	83.1	87.3	87.6
40	92.0	92.6	91.4	93.1	92.0	83.2	88.2	89.4
44	92.0	92.6	91.5	93.2	92.4	83.8	88.2	89.4
48	92.0	92.6	91.6	93.4	92.4	83.8	..	..
52	92.3	92.6	91.7	93.4	..	..	..	..
56	92.3	92.6	..	..	..	..	..	..

seed the longer the period required for germination.

In a subsequent test, seeds harvested at the same time were stored for various periods before germinating. The data presented in Table 1 show that seeds planted 3 days to 6 months after harvest required approximately 1 year to produce a germination of about 90 per cent. Seeds planted 8 to 12 months after harvest were delayed in emergence. It appears that these seeds will require approximately 4 years to attain a germination of 90 per cent.

In a final experiment, the germination of old seeds was studied. The percentage germination of 17-month-old seed was 60.7, 66.8, 68.3, and 69.2 at the end of the first, second, third, and fourth years, respectively. At the end of similar periods, the percentage germination of 10-year-old seed was 56.6, 66.0, 67.6, and 71.7, respectively.

The data presented show that the time required for maximum germination of untreated koa haole seed under optimum conditions in the soil varied from 1 to 4 or more years, depending on the number of hard seeds. Prolonged storage under ordinary conditions tends to extend the dormant period. Koa haole seeds remain viable at ordinary storage conditions for as long as 10 years.

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Allometric Growth in the Striped Marlin, *Makaira mitsukurii*, from New Zealand[1]

JAMES E. MORROW, JR.[2]

INTRODUCTION

MEASUREMENTS MADE on 49 striped marlin obtained by the Yale–New Zealand Expedition, 1948, are the basis for this study. The fish were caught on rod and line between January 31 and March 3, 1948, near Cape Brett, New Zealand. The majority (36) were taken in the immediate vicinity of Cape Brett, at the mouth of the Bay of Islands, while the remaining 13 were caught near the Cavalli Islands, about 20 miles to the northwest. Thirty of the fish were caught by members of the expedition. For the privilege of examining the remaining 19, it is our pleasant duty to extend our thanks to the guests of Otehei Lodge, Otehei Bay, New Zealand. We also wish to thank the proprietors, Mr. and Mrs. G. J. Hassall, and their staff for their generous co-operation and for the excellent working facilities which they furnished us.

The fish measured in this work ranged between 201.9 and 286.5 centimeters in standard length. This is, then, an examination of allometry in adult animals. Ideally, a study of this type would include specimens from the smallest postlarva to the largest adult, thereby providing indices to the growth patterns at all ages and showing when and how these growth patterns change. Because of the methods of capture available to us, however, we were unable to do more than examine fish of a size commonly taken on rod and line. The world's record for striped marlin is 409 centimeters in total length (about 325 cm. in standard length), and marlin less than about 150 centimeters are rarely if ever taken on rod and line. Since our specimens range from 201.9 to 286.5 centimeters in standard length, we are thus dealing here neither with the largest nor the smallest, but rather with the middle portion of the adult size range.

Studies of allometric growth are applicable to a number of broad problems. They may help to elucidate the laws governing the growth of animals and establish general principles of wide application. They may provide a clue to the mechanics of raciation, speciation, and evolution; changing growth patterns, both ontogenetic and phylogenetic, are indicators that these phenomena are taking place. They may indicate whether or not a widely ranging species is homogeneous or composed of a number of separate populations, information which is often vital to the fisheries biologist or conservationist. It was with particular reference to this last point that the measurements here recorded were made. These measurements should be especially valuable to workers who gather similar data on this species in different parts of the world.

MATERIALS AND METHODS

All big-game fish brought in to Otehei Bay were weighed on the official scale of the Bay of Islands Swordfish and Mako Shark Club by G. J. Hassall, weighmaster. Linear measurements were made by us with a tape

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[1] Scientific results of the Yale–New Zealand Expedition, 1948.

[2] Bingham Oceanographic Laboratory, Yale University, New Haven, Conn. Manuscript received December 26, 1950.

graduated to ¼ inch and read to the nearest ⅛ inch. For convenience in calculating, inches were later converted to centimeters and pounds to kilograms. These converted measurements are listed in Table 1. It may be added here that measurements made with a tape are not completely satisfactory. As a result of this experience, we suggest the use of large calipers, which can be laid parallel to the long axis of the body and the arms of which are long enough to encompass the greatest depth of the animal. In this way, accuracy will be greatly enhanced.

Throughout this study, use has been made of the logarithmic growth equation, $Y = bX^k$, or $\log Y = \log b + k \log X$, where Y = length of body part, X = standard length, b = initial growth index, k = equilibrium constant (Huxley, 1932: 4–8; Huxley and Teissier, 1936: 780). In the use of this equation, $k = 1$ indicates isometry, with the portion under consideration increasing in size at the same rate as the standard length. Similarly, k greater or less than 1 indicates positive or negative allometry, with the body parts increasing at a greater or lesser rate than the standard length. Note also that the units of the body parts are not necessarily equal to the units of the standard length, but are related to them through a factor represented by the constant b. Thus, if X changes by 1 meter and Y changes by only 1 centimeter, then $k = 1.0$ and $b = 0.01$.

With respect to the length–weight relationship, it should be noted that weight is equal to density times volume. Since volume is the resultant of three dimensions, length, breadth and depth, the length–weight relationship is thus a cubic rather than a linear one. Isometry of length and weight, therefore, must be indicated by $k = 3$. In the same way as before, k greater or less than 3 indicates that weight is increasing more or less rapidly than the cube of length, and also shows that the three linear components of weight do not vary at the same rate.

Each set of measurements was plotted on a double logarithmic scale and regression equations were fitted by the method of least squares. The significance of deviations from isometry was tested by methods outlined by Snedecor (1948: 103–168) and Simpson and Roe (1939: 186–284). Comparisons of k values followed the methods of Snedecor (1948: 318–339) and Simpson and Roe (1939: 277–280). The standard length was always measured along the central axis of the body from the tip of the sword to the center of the notch on the caudal peduncle. Other measurements are described in the appropriate sections.

There appears to be but little data in the literature on allometry in the striped marlin. Gregory and Conrad (1939: Table 1) give detailed measurements of 17 specimens (standard lengths from 250.8 to 284.0 cm.) from Cape Brett, N. Z., and nine specimens (standard lengths from 203.0 to 286.0 cm.) from Mayor Island, N. Z. Shapiro (1938: 1–20) has examined growth patterns in the blue marlin (*Makaira nigricans ampla*) of the Atlantic from 195.0 to 304.0 centimeters in standard length. Where appropriate, we have compared the patterns shown by our sample with the data given by these authors.

GROWTH PATTERNS

The Length–Weight Relationship

In the vast majority of fishes which have been examined from this standpoint, the equilibrium constant of weight on length is approximately 3. However, wide variations have been recorded, from as low as 1.4 (Hile, 1936: 243) to over 3.9 (Shapiro, 1938: 5), in various species. Indeed, comparable variations are to be found between different populations of the same species (e.g., the cisco, *Leucichthys artedi*, according to Hile, varies approximately from 1.4 to 3.7. Although sampling errors may often account for a large portion of the deviations in this relationship (Morrow, 1951: 20–22), real differences in the length–weight relationship undoubtedly in-

TABLE 1

MEASUREMENTS OF STRIPED MARLIN EXAMINED AT OTEHEI BAY, BAY OF ISLANDS, N. Z.*

SPECIMEN NUMBER	WEIGHT	STANDARD LENGTH	SWORD LENGTH	EYE	DORSAL FLUKE OF CAUDAL FIN	VENTRAL FLUKE OF CAUDAL FIN	EYE TO PECTORAL	DEPTH	GIRTH	PECTORAL LENGTH
5	93.4	252.0	61.6	5.9	61.0	—	33.6	43.2	106.0	53.0
6	98.0	255.0	68.9	—	57.8	55.9	29.9	45.7	107.8	—
7	89.4	261.0	67.6	6.0	57.8	57.2	31.1	44.2	102.2	52.1
8	142.0	281.3	66.4	7.0	62.8	58.4	34.3	51.4	115.5	53.3
9	102.5	263.5	71.4	6.0	62.2	58.4	28.6	43.2	107.8	55.6
10	41.3	201.9	52.1	4.8	55.0	50.2	22.9	32.1	79.4	—
17	78.0	247.8	66.6	6.0	61.6	57.8	29.2	38.7	95.2	52.7
18	112.0	261.3	66.6	5.7	68.9	62.6	28.6	40.0	104.4	55.9
21	104.3	253.4	65.4	6.3	64.8	57.1	27.6	41.9	107.9	48.3
38	120.2	259.0	67.3	6.3	64.8	58.7	29.8	—	—	52.1
43	103.0	262.3	67.6	7.0	62.9	59.7	29.2	45.4	113.6	51.7
45	93.9	253.8	69.5	6.0	66.0	60.9	27.3	41.9	104.0	55.9
46	84.4	241.5	65.4	5.7	60.0	54.3	27.3	42.9	102.8	48.9
48	97.1	255.3	63.5	6.3	64.1	59.1	28.6	42.5	107.9	50.1
49	69.8	229.3	61.9	5.7	60.9	54.9	25.4	38.1	91.4	54.6
50	94.3	237.2	65.1	6.0	60.6	54.3	26.4	44.4	105.4	48.6
52	136.1	286.5	74.3	7.0	69.2	66.0	33.0	50.5	118.1	55.2
53	122.5	279.0	71.1	6.7	—	64.1	33.7	47.0	—	57.8
54	117.0	255.1	62.8	7.0	58.4	57.2	31.7	45.7	—	59.7
55	88.0	257.2	69.2	6.3	66.0	63.5	30.2	38.7	—	54.0
56	82.6	255.2	68.6	6.0	61.0	56.5	27.9	37.5	97.2	50.2
61	—	230.9	60.3	6.3	60.3	54.0	27.9	42.5	102.6	49.5
62	131.1	262.9	67.0	6.7	66.0	59.7	33.4	48.2	119.4	57.8
63	88.0	256.8	70.8	6.0	64.8	59.1	27.9	41.9	100.3	57.2
65	83.5	251.4	69.8	6.3	59.7	50.9	28.6	—	—	49.5
66	128.4	270.0	66.6	7.0	—	—	31.1	—	—	61.6
67	94.3	268.5	69.2	6.0	64.1	58.4	30.5	43.2	104.1	57.2
69	108.0	273.7	72.4	7.0	63.5	59.0	30.2	45.7	106.6	57.5
70	93.4	263.0	75.8	6.0	66.0	61.3	29.2	44.1	104.7	60.3
71	76.7	240.0	63.2	5.7	62.2	55.2	27.3	40.0	95.2	49.8
72	109.3	261.5	70.8	6.0	67.3	64.1	30.5	46.1	112.4	55.8
73	123.4	272.4	72.0	6.7	67.0	60.9	30.2	45.7	116.1	54.2
74	93.9	256.2	66.6	6.3	65.1	60.0	29.8	43.5	105.3	52.7
75	89.4	247.6	64.8	6.0	65.7	58.8	26.7	43.8	104.7	53.3
80	104.3	261.0	68.9	5.7	68.9	63.8	29.8	45.7	109.1	61.6
82	73.0	243.9	67.9	6.3	64.1	59.7	28.3	39.1	93.9	53.3
83	102.1	270.0	69.2	7.3	63.5	58.1	31.1	44.8	107.2	54.6
84	97.1	263.1	71.1	6.3	66.6	61.6	30.2	44.4	107.2	57.5
87	129.3	275.1	68.9	6.7	69.8	64.8	31.7	48.6	116.1	59.0
99	135.2	283.9	71.7	7.0	69.8	60.0	33.3	48.9	115.1	57.8
114	139.7	282.0	76.2	6.7	71.1	64.1	31.5	49.5	120.6	60.3
115	152.4	266.0	61.9	6.7	70.8	64.8	32.4	49.9	119.3	59.7
116	105.7	270.5	68.6	6.7	63.5	57.2	29.5	41.9	104.0	53.3
117	102.5	258.8	67.3	6.3	61.9	57.2	27.9	42.5	107.2	51.4
118	111.6	249.3	55.6	6.3	64.8	59.1	29.8	45.7	107.8	53.3
120	97.5	233.8	41.3	6.7	64.8	61.6	30.4	44.4	108.5	51.4
121	98.0	265.5	69.2	6.3	64.1	60.0	29.8	43.2	106.6	55.2
122	82.1	266.7	62.2	6.3	62.8	56.5	27.9	42.2	100.3	52.4
123	102.5	257.9	63.5	6.0	58.4	55.9	29.6	43.8	106.6	52.7

*Weight in kilograms, other measurements in centimeters.

dicate different growth patterns, either between species or at different times or in different populations of the same species.

The sample of striped marlin considered here has a length–weight equilibrium constant of 3.009. However, the standard error of k, s_k is 0.307, indicating the possibility of rather wide random variations in k which would not be significant. Shapiro (1938: 5) reported the equilibrium constant of weight on length for the Atlantic blue marlin as 3.93 for a sample of 23 specimens. The difference is quite reasonable, for the blue marlin is a much deeper-bodied fish. It is probable that the Pacific black marlin (*Makaira nigricans marlina*) might have an even higher constant. The white marlin (*Makaira albida*) seems to be a very slim fish and ought to have a considerably lower constant in its length–weight equation.

Linear Measurements

Statistics of the logarithmic regressions of the various linear measurements are given in Table 2. Significant departures from isometry were found in only two of these measurements, although two others, pectoral length on standard length and dorsal fluke of the tail on ventral fluke, approach a significant level. It is possible that examination of larger samples might show the allometry of these dimensions to be significant.

The length of the sword, from the tip to the anterior margin of the eye, maintains an isometric relationship to the standard length. The data published by Gregory and Conrad (*loc. cit.*) give values of k of 0.816 for 17 fish from Cape Brett and 0.889 for 9 fish from Mayor Island. Shapiro (1938: 15) gives k = 0.88 for the sword of the blue marlin. None of these figures represent a significant departure from isometry. This is somewhat surprising, for it is popularly assumed that the sword tends to become relatively shorter with increased overall length.

The anterior–posterior diameter of the eye shows a very slight degree of negative allo-

TABLE 2

STATISTICS OF THE LOGARITHMIC REGRESSIONS OF LINEAR MEASUREMENTS ON STRIPED MARLIN FROM NEW ZEALAND

LOG INDEPENDENT VARIABLE, X	LOG DEPENDENT VARIABLE, Y	N	MEAN LOG X	MEAN LOG Y	$S_{(\log X)^2}$*	$S_{(\log Y)^2}$*	$S_{(\log X \cdot \log Y)}$*	$S_{(\log Y \cdot \log X)}$**	K†	s_K‡
Standard length	Sword length	49	2.411	1.822	0.036458	0.087978	0.036704	0.041	1.007	0.216
	Eye	48	2.411	0.799	0.035588	0.053982	0.030529	0.025	0.858	0.130
	Dorsal fluke	47	2.410	1.805	0.033822	0.029052	0.018744	0.020	0.554	0.111
	Ventral fluke	47	2.411	1.770	0.035004	0.032039	0.021378	0.021	0.611	0.110
	Eye to pectoral	49	2.411	1.471	0.036458	0.064622	0.033859	0.027	0.929	0.139
	Depth of body	46	2.411	1.640	0.034979	0.064699	0.034926	0.026	0.998	0.139
	Girth	43	2.410	2.025	0.033704	0.049169	0.031298	0.022	0.929	0.121
	Pectoral length	47	2.413	1.735	0.023977	0.037343	0.016959	0.024	0.707	0.153
Ventral fluke	Dorsal fluke	46	1.769	1.805	0.030645	0.028653	0.025845	0.012	0.843	0.071

* $S_{(\log x)^2}$, $S_{(\log y)^2}$, $S_{(\log x \cdot \log y)}$ = sums of squares and products about mean log X and mean log Y.

** $s_{(\log y \cdot \log x)}$ = standard error of estimate.

† k = regression coefficient of log Y on log X.

‡ s_k = standard error of regression coefficient.

metry, but again this is not significant. The measurements made by Gregory and Conrad also do not indicate significant allometry in the eye.

It was not possible to measure the distance between the posterior edge of the eye and the pectoral base along the mid-line of the body with reasonable accuracy, so this measurement was made directly between the eye and the anterior margin of the pectoral base. This distance is distinctly isometric. Even though this is a slanted measurement, it is close enough to the mid-line so that, in combination with the isometry of the sword length, it suggests that the relative length of the head also remains constant.

When the length–weight relationship is isometric, as in the present example, the same condition is to be expected in depth and girth, for these two dimensions may be considered as linear components of weight. One of the more obvious differences in body form between the striped marlin and the blue and black marlins is illustrated more simply by the isometry of these measurements than by the length–weight relationship. In the striped marlin, the equilibrium constants for depth and girth are 0.998 and 0.929, respectively. Shapiro (1938: 7) reports $k = 1.45$ for depth of body in the blue marlin. We have found no data on the black marlin, but Nichols and LaMonte (1941: 8) describe this species as "Heavier at larger sizes . . .," which certainly suggests positive allometry in depth and girth. Thus, the greater depth of the body in the blue and black marlins is reflected in the higher equilibrium constants.

The length of the longest ray of the pectoral fin shows slight negative allometry, with $k = 0.707$, $P = 0.065$. This slight negative allometry is not shared by either of the samples examined by Gregory and Conrad.

The two flukes of the caudal fin were measured along their slant lengths from the anterior end of the corresponding peduncular keel to the tip of the longest ray. The tail is distinctly epibatic. The dorsal fluke is always slightly longer than the ventral, although there is a tendency in these adult animals for the tail to become more nearly symmetrical with greater size. Comparison of the two flukes shows that the dorsal fluke is negatively allometric with respect to the ventral fluke, with $k = 0.843$, $s_k = 0.071$, $P < 0.05$. Thus, the rate of growth of the dorsal fluke relative to the rate of growth of the ventral fluke decreases as the gross size of the flukes increases.

With respect to the standard length, both the dorsal and ventral moieties of the caudal fin exhibit highly significant degrees of negative allometry in this sample. For the dorsal fluke, $k = 0.554$, for the ventral fluke, $k = 0.611$. Both these values represent departures from isometry which are significant at $P < 0.001$. Thus, the rate of growth of the tail relative to the rate of growth of the fish as a whole tends to decrease rapidly with greater size in adult animals.

It is interesting to compare these data on the tail with those derived from the measurements published by Gregory and Conrad (*loc. cit.*). Their group of 17 specimens from Cape Brett shows negative allometry in the lengths of the caudal flukes quite comparable to that reported here for fish from the same area.

By contrast, their sample of nine fish from Mayor Island, some 175 miles to the southeast, exhibits positive allometry in both the dorsal and ventral flukes, although this allometry is of a low order of significance ($P = 0.09$ for the dorsal flukes and 0.04 for the ventral flukes). Nevertheless, there appears to be a real difference between the two geographical groups as shown by a comparison of the k values for the nine fish from Mayor Island and those of the 47 fish of the present sample from the vicinity of Cape Brett ($P < 0.001$).

This suggests that the fish from Mayor Island and those from Cape Brett may represent separate populations. However, this suggestion is put forward most cautiously, for the growth patterns of the tail flukes are the only sets of measurements in which significant differences have been found to exist between the two groups.

SUMMARY

Application of the equation $Y=bX^k$ to measurements of 9 different body dimensions in a sample of 49 adult striped marlin from the region of Cape Brett, New Zealand, has shown that, in general, growth in these fish is isometric with the standard length of the body. Slight but not statistically significant negative allometry was found in the length of the longest ray of the pectoral fin. Significant negative allometry was found in the dorsal and ventral flukes of the caudal fin. A significant difference in the growth pattern of the tail was found to exist between the sample reported here and a sample of nine fish of similar size from Mayor Island, New Zealand, examined by Gregory and Conrad. It is suggested that these two samples may represent separate populations.

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Variation in the Vertebral Number of the Anchovy *(Stolephorus purpureus)* in Hawaiian Waters[1]

Albert L. Tester and Robert W. Hiatt[2]

A STUDY OF VARIATION in vertebral number of the nehu, *Stolephorus purpureus* Fowler, from various localities throughout the Territory of Hawaii, has been undertaken in an effort to determine whether one or several populations of this small but valuable baitfish exist. Large quantities of nehu are caught each year on several different baiting grounds and are used in livebait fishing for the aku or skipjack. A recent scarcity of bait in some areas has posed the question of whether the stock is being overfished. Therefore, knowledge of whether each baiting area supports a separate population is of practical importance as well as of academic interest.

METHODS

Sampling

The study is based on 18 samples taken mostly from the commercial catch. Although efforts were made to secure random samples, some of those submitted by the fishermen may include a disproportionate number of smaller specimens, if, as is likely, they furnished fish which died in their baitwells. However, this would not influence the conclusions which have been drawn.

Some of the samples were taken from catches made at night by night-light nets; others were taken from catches made in the daytime by surround nets. These methods of fishing have been described by June (1951).

Seven different localities are represented: Ala Wai Canal, Honolulu Harbor, Pearl Harbor, and Kaneohe Bay on the island of Oahu; Kihei on the island of Maui; and Hilo Harbor and Kawaihae Bay on the island of Hawaii (Fig. 1). Unfortunately no samples were obtained from other important baiting grounds on the islands of Kauai and Molokai.

The samples were collected as occasion permitted over a period of years, from 1944 to 1949. There was no particular pattern as to time of collection or number examined. All samples were preserved in approximately 10 per cent formaldehyde.

Preparation of Vertebral Columns

Two methods of preparing the vertebral columns for counting were used, the "photographic" and the "direct." In the photographic method the fish were subjected to the following procedure (a modified Spalteholz-type preparation):

(1) Wash in running water for 3 hours; or let stand in still water for 5 hours, changing the water every hour.

(2) Remove viscera, scales, and, in larger specimens, gills.

(3) Bleach for 1 to 3 hours in 3 per cent hydrogen peroxide until lateral line and peritoneum are clear.

(4) Wash for 1 hour in running water.

(5) Place in 1 per cent potassium hydroxide for a half hour and aspirate with water-vacuum pump to remove air bubbles from fish.

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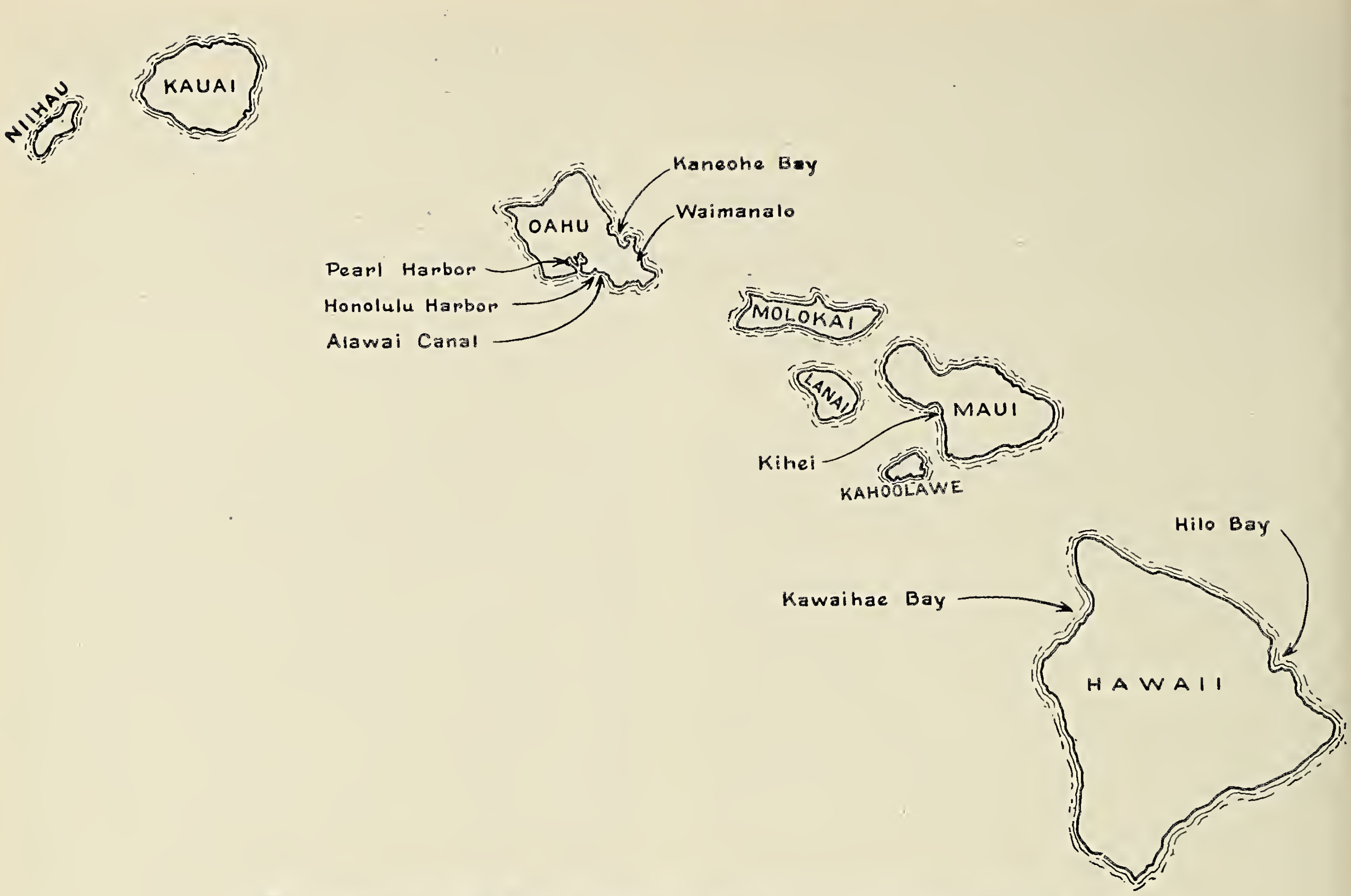

FIG. 1. Map of the Hawaiian Islands showing the localities sampled.

(6) Place in 4 per cent potassium hydroxide for 4 to 6 hours, until vertebrae can be seen clearly.

(7) Place in alizarin staining solution (see below), stain for 10 hours, then turn the fish over and stain the other side for 5 to 10 hours.

(8) Place, successively, in a series of 4 per cent potassium hydroxide–glycerin solutions (90:10; 80:20; 60:40; 20:80; 0:100), each for 12 hours; if a solution turns dark red-blue, repeat that particular solution.

(9) Preserve in 100 per cent glycerin, adding two or three small crystals of thymol to prevent the growth of molds; all parts of the fish, except the bones, are now transparent.

(10) Place the fish in a container filled with glycerin and, using a standard Kodak enlarger, project the image on photographic paper, expose, and develop (Fig. 2); several fish may be photographed simultaneously.

(11) Using the photograph, count the number of vertebrae.

In the direct method, the fish were prepared in the following manner:

(1) Wash in running water for 1 to 3 hours.

(2) Using a scalpel, slice the flesh from the caudal peduncle to the head on the left side of the fish, cutting to, but not into, the column; using scissors, snip the flap of flesh diagonally across the head, thus exposing the base of the skull and the first vertebra; using scalpel, scrape the remaining flesh from the column on the left side of the fish and remove viscera from body cavity.

(3) Place the fish in staining solution for 4 hours.

(4) Transfer to water or to 5 per cent formaldehyde solution; some de-staining will occur.

(5) Count the vertebrae under the low-power binocular microscope, using a pointer (eyelash hair) in the ocular as a reference point.

A stock solution of stain was made by dis-

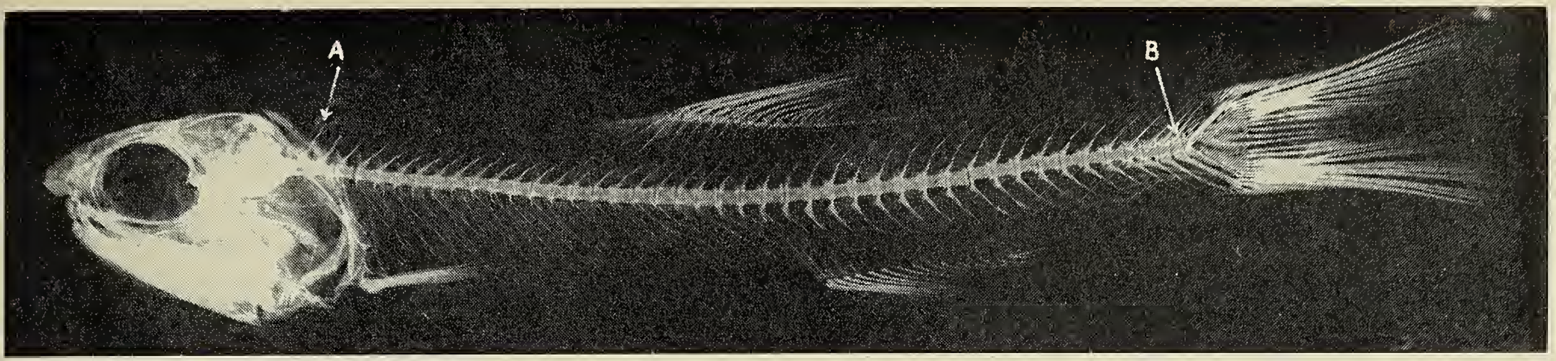

FIG. 2. Vertebral column prepared by the "photographic" method. Note the anterior (A) and posterior (B) end points in counting.

solving 1 gram of Alizarine Red S. in 500 milliliters of 3 per cent potassium hydroxide solution. The staining solution consisted of 10 milliliters of the stock solution added to 100 milliliters of 3 per cent potassium hydroxide.

In counting the vertebrae, both end points were clearly defined. The first vertebra was readily identified by its high spine with a small triangle of cartilage *both* anterior and posterior to it. The last vertebra was identified as the one immediately anterior to the upturned, segmented urostyle. These end points may be seen in Figure 2. Thus the count, which was checked at least once for each fish, included neither the basioccipital nor the urostyle.

Both methods of preparation were satisfactory. However, the first method was time consuming, and in several cases it was difficult to get the column in clear focus along its entire length for photographing. The second method is recommended. With its use, a small number of vertebral columns with abnormal centra (6 cases out of 851) were detected, and the counts on these abnormal specimens were discarded.

Length Measurements

Length measurements were made on all samples, but in one from Kaneohe Bay (10/25/47), they were not identified with vertebral number. Standard length is defined as the distance (measured to the nearest millimeter) from the tip of the upper jaw to the posterior edge of the hypural plates. In specimens which were photographed, the length was determined with dividers and was measured on a scale which was photographed with the fish. For specimens in which the vertebrae were counted under the microscope, the length was measured directly with vernier callipers.

RESULTS

In a sample from Kaneohe Bay (10/25/47) in which the sexes were segregated, the mean vertebral number for 76 males was 42.618 and for 76 females, 42.645. The difference of 0.027 had a standard error of 0.095. A difference of this magnitude could arise readily from chance variation. It was concluded that sex need not be considered as a source of variation in mean vertebral number. This conclusion is in accord with those found by most workers in other species, e.g., Tester (1937) in Pacific herring (*Clupea pallasii*) and Blackburn (1950) in the Australian anchovy (*Engraulis australis*), but it is in contrast with that found by Hart (1937) for the Pacific capelin (*Mallotus villosus*).

In the Pacific herring (McHugh, 1942), there is a tendency for the mean vertebral number to be higher in larger fish, a phenomenon which is presumed to be related to hereditary differences in the developmental rate of individuals. To investigate this possibility in the nehu, the fish of each sample were grouped in 3-millimeter-length categories and the mean count for each was determined. The results, for length categories including 10 or more fish, are shown in Table 1 and Figure

3A. In the figure, the mean count of each length group is plotted as a deviation from the mean count of the sample.

It will be noted from Figure 3A that, in some samples, mean vertebral number tends to increase with length, in others it tends to decrease, and in still others it shows no apparent relationship. Using the original ungrouped data it was found that either positive or negative regressions of vertebral number on length could be statistically significant. For example, in a sample from Ala Wai Canal (5/22/44) the positive regression coefficient of 0.0222 over all lengths had a standard error of 0.00863 and differed significantly from zero (P = 0.02). Also, in a sample from Honolulu Harbor (3/3/49) the negative regression coefficient of —0.0355 over length groups 24 to 40 millimeters (Fig. 3A) had a standard error of 0.0162 and differed significantly from zero (P = 0.04).

Before attempting to interpret the above results, it should be pointed out that the spawning period of the nehu in those localities which have been investigated (Ala Wai Canal and Kaneohe Bay) extends throughout the entire year. Moreover, the period between fertilization and hatching of the egg is very short—24 hours or less.

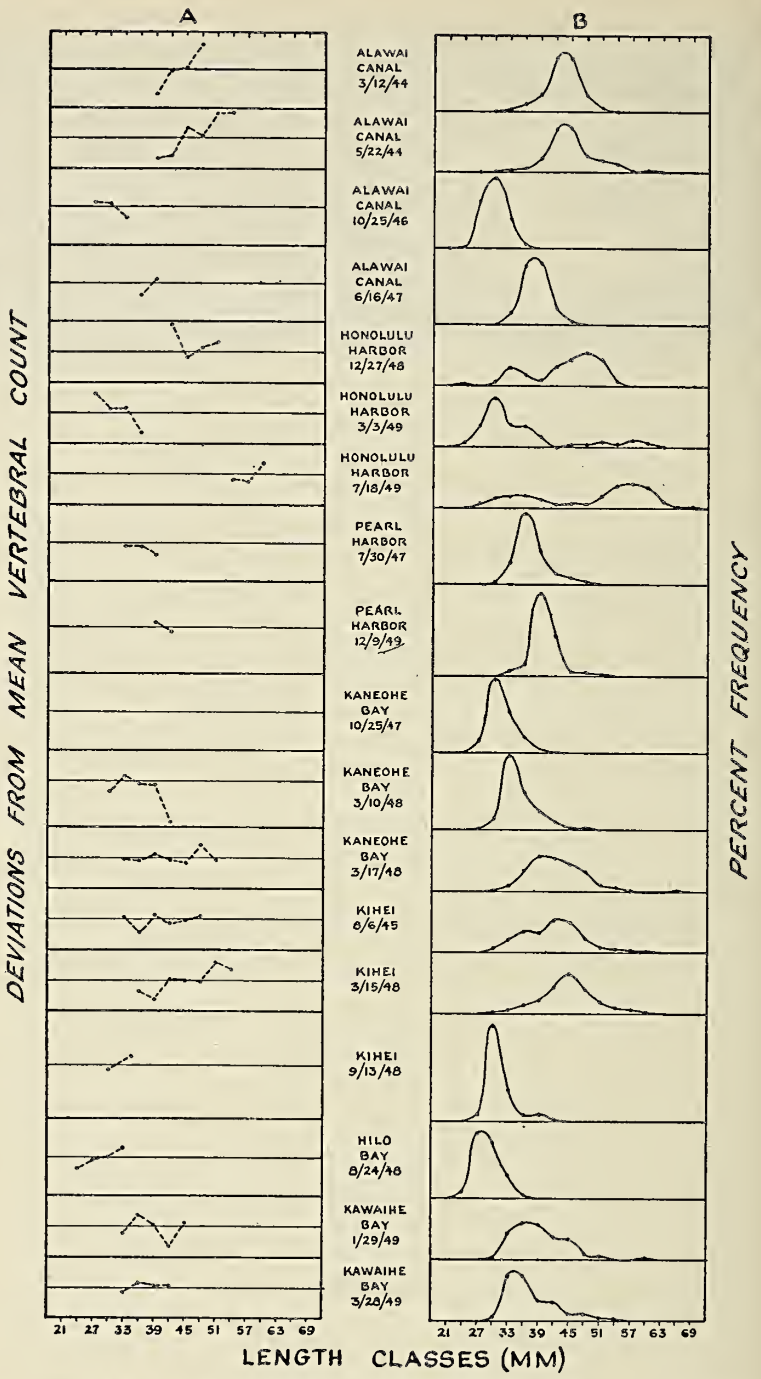

FIG. 3. A, Variation in mean vertebral count with length; B, length frequency distributions of the samples.

If, as in many other plastic species, vertebral number is influenced by environmental conditions obtaining during the time of embryonic and early larval development, variation in environmental conditions from day to day might produce variation in the mean vertebral number of successive day-broods. In some species, e.g., herring—*Clupea pallasii* (Tester, 1938)—there seems to be an inverse relationship between mean vertebral number and water temperature during the period of early development, low mean counts being associated with high temperatures, and vice versa. In others, e.g., the Pacific anchovy—*Engraulis mordax* (Hubbs, 1925)—there seems to be a direct relationship between mean vertebral number and salinity, the low mean counts being associated with less saline, brackish water conditions, and vice versa. Therefore, in the nehu, upward or downward trends in temperature or salinity, extending over a period of days or weeks, might produce downward or upward trends in mean vertebral number within the length range of a sample, thus explaining the occurrence of both positive and negative regressions. It is not necessary to postulate an inherited tendency for fast-growing, larger individuals of one brood to have a higher count than slow-growing, smaller individuals of the same brood, although the tendency may still exist.

The length frequency distributions of the

TABLE 1

VERTEBRAL COUNTS OF NEHU, WITH MEANS ACCORDING TO LENGTH GROUPS (10 OR MORE SPECIMENS, ONLY) AND SAMPLES (ALL SPECIMENS)

LOCALITY AND DATE	LENGTH GROUP	NUMBER OF FISH WITH COUNTS OF					TOTAL NUMBER	MEAN FOR	
		40	41	42	43	44		LENGTH GROUP	ENTIRE SAMPLE
Ala Wai Canal, Oahu 3/12/44	39	1	7	3	–	–	11	41.182	
	42	2	14	19	–	–	35	41.486	
	45	2	14	18	1	–	35	41.514	
	48	–	3	7	1	–	11	41.818	
	All	5	43	50	2	–	100	—	41.490
Ala Wai Canal, Oahu 5/22/44	39	2	14	3	2	–	21	41.238	
	42	3	40	19	1	–	63	41.286	
	45	2	21	40	1	–	64	41.625	
	48	2	9	13	1	–	25	41.520	
	51	–	4	12	1	–	17	41.824	
	54	1	3	6	3	–	13	41.846	
	All	13	106	110	12	–	241	—	41.502
Ala Wai Canal, Oahu 10/25/46	27	–	12	20	3	–	35	41.743	
	30	1	15	34	2	–	52	41.712	
	33	1	9	11	1	–	22	41.545	
	All	3	37	66	7	–	113	—	41.681
Ala Wai Canal, Oahu 6/16/47	36	1	8	10	–	–	19	41.474	
	39	–	10	9	1	–	20	41.550	
	All	2	22	24	1	–	49	—	41.490
Honolulu Harbor, Oahu 12/27/48	33	–	1	7	2	–	10	42.100	
	42	–	–	3	8	–	11	42.727	
	45	–	1	9	5	–	15	42.267	
	48	–	–	12	6	1	19	42.421	
	51	–	–	8	7	–	15	42.467	
	All	–	2	54	31	–	88	—	42.352
Honolulu Harbor, Oahu 3/3/49	27	–	–	1	11	2	14	43.071	
	30	–	1	6	25	3	35	42.857	
	33	–	–	4	10	2	16	42.875	
	36	–	–	7	8	–	15	42.533	
	All	–	1	26	74	7	108	—	42.806
Honolulu Harbor, Oahu 7/18/49	54	–	1	8	7	–	16	42.375	
	57	–	1	9	7	–	17	42.353	
	60	–	–	6	9	–	15	42.600	
	All	–	8	46	50	3	107	—	42.449
Pearl Harbor, Oahu 7/30/47	33	–	–	10	2	–	12	42.167	
	36	–	3	26	9	–	38	42.158	
	39	–	4	9	5	–	18	42.055	
	All	–	7	52	24	–	83	—	42.205

TABLE 1 (*cont'd*)

LOCALITY AND DATE	LENGTH GROUP	NUMBER OF FISH WITH COUNTS OF					TOTAL NUMBER	MEAN FOR	
		40	41	42	43	44		LENGTH GROUP	ENTIRE SAMPLE
Pearl Harbor, Oahu 12/9/49	39	–	1	30	28	3	62	42.532	
	42	–	1	16	13	–	30	42.400	
	All	–	2	57	50	4	113	—	42.496
Kaneohe Bay, Oahu 10/25/47	All	–	12	262	335	16	625	—	42.568
Kaneohe Bay, Oahu 3/10/48	30	–	–	7	11	–	18	42.611	
	33	–	2	27	80	7	116	42.793	
	36	–	1	18	38	3	60	42.717	
	39	–	–	10	19	1	30	42.700	
	42	–	–	5	6	2	13	42.231	
	All	–	3	68	159	14	244	—	42.754
Kaneohe Bay, Oahu 3/17/48	33	–	–	3	7	–	10	42.700	
	36	–	–	13	18	2	33	42.667	
	39	–	–	18	34	4	56	42.750	
	42	–	3	13	35	2	53	42.679	
	45	–	–	17	25	1	43	42.628	
	48	–	–	7	21	3	31	42.871	
	51	–	–	3	7	–	10	42.700	
	All	–	3	79	151	13	246	—	42.707
Kihei, Maui 8/6/45	33	–	–	3	7	–	10	42.700	
	36	–	–	9	6	1	16	42.500	
	39	–	–	5	9	1	15	42.733	
	42	–	–	9	15	–	24	42.625	
	45	–	–	8	13	1	22	42.682	
	48	–	–	4	6	1	11	42.727	
	All	–	–	45	65	6	112	—	42.688
Kihei, Maui 3/15/48	36	–	–	6	7	–	13	42.538	
	39	–	–	13	10	–	23	42.435	
	42	–	–	17	24	3	44	42.682	
	45	–	–	23	39	2	64	42.672	
	48	–	–	15	22	2	39	42.667	
	51	–	–	4	13	2	19	42.895	
	54	–	–	2	9	–	11	42.818	
	All	–	–	85	134	9	228	—	42.667
Kihei, Maui 9/13/48	30	–	–	24	36	6	66	42.727	
	33	–	–	6	11	4	21	42.905	
	All	–	–	33	59	12	104	—	42.798
Hilo Bay, Hawaii 8/24/48	24	–	1	6	5	1	13	42.462	
	27	–	–	54	64	3	121	42.579	
	30	–	3	41	55	6	105	42.610	
	33	–	–	13	29	1	43	42.721	
	All	–	4	117	155	12	288	—	42.608

TABLE 1 (*cont'd*)

LOCALITY AND DATE	LENGTH GROUP	NUMBER OF FISH WITH COUNTS OF					TOTAL NUMBER	MEAN FOR	
		40	41	42	43	44		LENGTH GROUP	ENTIRE SAMPLE
Kawaihae Bay, Hawaii 1/29/49	33	–	–	12	12	1	25	42.560	
	36	–	–	9	24	2	35	42.800	
	39	–	–	13	18	2	33	42.667	
	42	–	–	14	6	1	21	42.381	
	45	–	–	8	10	2	20	42.700	
	All	–	–	59	77	9	145	—	42.655
Kawaihae Bay, Hawaii 3/28/49	33	–	–	12	20	4	36	42.778	
	36	–	1	4	28	3	36	42.917	
	39	–	–	4	10	2	16	42.875	
	42	–	1	3	8	3	15	42.867	
	All	–	2	29	78	14	123	—	42.845

samples are shown in Figure 3B, the number in each length category being represented as a percentage of the total number in the sample. There is considerable variation between samples in both the length range and the position of the mode. Two of the samples, both from Honolulu Harbor, have at least two modes. In the first (12/27/48) the mean vertebral number for the smaller modal group (less than 39 mm.) is 42.136, and for the larger modal group (greater than 39 mm.), 42.431. The difference of 0.295 has a standard error of 0.133 and is significant (P = 0.03). In the second (7/18/49) the mean of the smaller group (less than 45 mm.) is 42.459 and of the larger group (greater than 45 mm.), 42.443. In this case, the difference of 0.016 has a standard error of 0.146 and is not significant. Again, differences such as these, if real, might be induced by differences in environmental conditions during the period of early development.

In the preceding paragraphs it has been shown that variation other than that due to chance may occur between length groups within samples. Accordingly, more generally to assess its significance and to allow for it in comparisons between samples, this source of variation was included in an analysis of variance of the data, considering the sampling to have been completely randomized. The analysis, limited to length groups containing 10 or more individuals, is summarized in the following tabulation:

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F
Localities	6	451.2679	75.2113	37.59**
Samples	10	20.0099	2.0010	4.09**
Length groups	55	26.8984	0.4891	1.39*
Individuals	2119	743.3730	0.3508	

** Highly significant; P is 0.01 or less.
* Significant; P is 0.05 or less, but greater than 0.01.

From a comparison of these F values with those tabulated for homogeneous distributions by Snedecor (1946: 10.4), it will be found that significant heterogeneity occurs between length groups of the same sample, between samples of the same locality, and between localities. The component of variance associated with "length groups" is obviously small. The conclusion for "samples" would have remained the same if the sum of squares and degrees of freedom for "length groups" and "individuals" had been pooled, and the resultant mean square used as the error term in testing this next higher category. In view of this, a second analysis, which does not allow for variation between length groups but which includes all the data rather than only some of them, was undertaken with the following results:

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F
Localities	6	520.2088	86.7015	31.97**
Samples	11	29.8275	2.7116	7.61**
Individuals	3099	1103.7526	0.3562	

** Highly significant; P is 0.01 or less.

As in the previous analysis, it is apparent that there are significant differences between the means for samples from the same locality and between the means for localities. The various means are tabulated in Table 2.

Heterogeneity between the means of samples from the same locality arises chiefly from the material taken at Honolulu Harbor and Kaneohe Bay. In the former, the mean of one sample (42.806) differs significantly from those of the other two (42.352 and 42.449). In the latter, the mean of one sample (42.568) also differs significantly from those of the other two (42.754 and 42.707). Differences such as these may represent: (1) the presence of two or more genetically separate stocks within a locality; (2) the mixture of stocks between localities; or (3) seasonal variation in environmental conditions within a locality, the stock remaining discrete.

Regarding (1), although the possibility of genetically separate stocks occurring within a locality cannot be ruled out, it seems unlikely that these would occur in fish, such as the nehu, which have pelagic eggs, and which spawn in partially enclosed waters with good circulation and mixing. Regarding (2), the possibility of schools migrating from one baiting area to another cannot be denied. However, as will be brought out in the discussion, there is little evidence that nehu schools occur commonly in offshore waters. Regarding (3), there is a difference of about 3°C. between summer and winter water temperatures within a locality. This, or seasonal differences in salinity, or a combination of both, may be sufficient to induce the differences in mean count between samples within localities.

The analysis-of-variance tables show that there is highly significant heterogeneity between localities, allowing for the variation between samples from the same locality. Inspection of the data (Table 2) indicates that the heterogeneity stems mostly from material for the island of Oahu. The mean for Ala Wai Canal (41.539) is outstandingly low as compared with the means for all other localities. To determine whether it differs significantly from those of other Oahu localities, the mean square for "samples" was accepted as a common variance (Snedecor, 1948: 10.4), thus leading to a calculation of the fiducial interval ($P = 0.05$) of a locality mean, which amounts to ± 0.279. The upper "limit" for Ala Wai Canal (41.818) is much less than the lower "limit" for Pearl Harbor (42.093), the locality with the closest mean count. It seems certain that the Ala Wai Canal fish constitute a distinct statistical group in respect to vertebral number, and that they mix little, if at all, with the fish of other localities.

The striking difference between the mean vertebral number of Ala Wai Canal nehu and those of other localities may be due to genetic factors, environmental factors, or both. The probability that the difference is of genetic origin could be investigated only by conducting rearing experiments on Ala Wai Canal fish and those of other areas under controlled conditions. The possibility that the difference is of environmental origin may be investigated with such data as are on hand. Surface temperatures and chlorinities over the period February to June, 1949, are available for three stations in both Ala Wai Canal and Kaneohe Bay. Average determinations, made within 1 or 2 days of each other, are shown in Table 3. During this period, Ala Wai Canal had a temperature which averaged about 0.7°C. higher and a chlorinity which averaged about 2.4 ppm lower than Kaneohe Bay. These, or even greater differences, are to be

TABLE 2

SUMMARY OF VERTEBRAL DATA. NUMBERS OF FISH AND MEAN COUNTS ACCORDING TO SAMPLE, LOCALITY, AND ISLAND

LOCALITY AND DATE	SAMPLE		LOCALITY		ISLAND	
	number	*mean*	*number*	*mean*	*number*	*mean*
Ala Wai Canal, Oahu						
3/12/44..................	100	41.490	503	41.539	2117	42.340
5/22/44..................	241	41.502				
10/25/46..................	113	41.681				
6/16/47..................	49	41.490				
Honolulu Harbor, Oahu						
12/27/48..................	88	42.352	303	42.548		
3/3/49..................	108	42.806				
7/18/49..................	107	42.449				
Pearl Harbor, Oahu						
7/30/47..................	83	42.205	196	42.372		
12/9/49..................	113	42.496				
Kaneohe Bay, Oahu						
10/25/47..................	625	42.568	1115	42.639		
3/10/48..................	244	42.754				
3/17/48..................	246	42.707				
Kihei, Maui						
8/6/45..................	112	42.688	444	42.703	444	42.703
3/15/48..................	228	42.667				
9/13/48..................	104	42.798				
Hilo Bay, Hawaii						
8/24/48..................	288	42.608	288	42.608	556	42.673
Kawaihae Bay, Hawaii						
1/29/49..................	145	42.655	268	42.743		
3/28/49..................	123	42.845				

TABLE 3

MEAN TEMPERATURE (°C.) AND CHLORINITY (PPM) AT THREE STATIONS IN ALA WAI CANAL AND KANEOHE BAY FOR CORRESPONDING TIMES

ALA WAI CANAL			KANEOHE BAY			DIFFERENCE	
Date	Temperature	Chlorinity	Date	Temperature	Chlorinity	Temperature	Chlorinity
2/4/49	24.6	13.62	2/3/49	23.3	17.42	1.3	−3.80
2/15/49	23.5	15.61	2/17/49	23.1	17.14	0.4	−1.53
3/7/49	24.7	16.56	3/8/49	23.5	17.19	1.2	−0.63
3/16/49	24.3	17.47	3/15/49	22.6	18.07	1.7	−0.60
3/21/49	24.3	17.19	3/22/49	23.8	17.57	0.5	−0.38
3/30/49	24.3	16.26	3/29/49	24.0	17.72	0.3	−1.46
4/13/49	24.2	13.15	4/12/49	23.1	18.24	1.1	−5.09
4/27/49	24.2	16.86	4/26/49	23.8	18.39	0.4	−1.53
5/2/49	24.7	17.47	5/3/49	24.8	18.73	−0.1	−1.26
5/16/49	26.7	16.82	5/17/49	26.0	19.47	0.7	−2.65
5/23/49	26.2	11.75	5/24/49	25.8	19.15	0.4	−7.40
6/8/49	26.3	16.20	6/7/49	26.0	18.22	0.3	−2.02
Mean difference						0.7	−2.38

expected, as Ala Wai Canal is a narrow inlet with a small opening to the sea and with a relatively large stream entering near its head, whereas Kaneohe Bay is a large body of water with a wide exposure to the sea and with a relatively small volume of fresh water entering it from a few streams. As the average difference in temperature between localities (0.7°C.) is much less than the average difference between summer and winter temperatures within localities (about 3° C.), it would appear that temperature alone could not account for the large difference in mean count between Ala Wai Canal (41.539) and Kaneohe Bay (42.639), although it is in the direction which might be expected.

Differences in mean vertebral count which are apparently related to differences in salinity have been reported by Hubbs (1925) for the Pacific Coast anchovy (*Engraulis mordax*), as noted above, and also by Blackburn (1950) for the Australian anchovy (*Engraulis australis*). In the former, the fish in the brackish waters of San Francisco Bay had a much lower mean count (43.80) than those near the entrance of the bay and seaward from the entrance (45.73). Similarly, in the latter, the fish in the brackish waters of the rivers of Gippsland lakes also had a lower mean count (44.56) than those near the entrance to the sea (45.20). Thus, the strikingly different mean count for the Ala Wai Canal fish is probably related in large part to the brackish-water habitat.

Inspection of Table 2 shows that not only is the mean for Ala Wai Canal (41.539) outstandingly low, but also that the means for other localities on the leeward shore of Oahu —Pearl Harbor (42.372) and Honolulu Harbor (42.548)—are lower than that of Kaneohe Bay (42.639) on the windward shore. One might be tempted to the conclusion that there are also distinct populations in these other localities. Consideration of their relative sizes, extent of exposure to the open sea, fresh-water supply, etc., would suggest that Oahu localities range in the following order of increasing average salinity: Ala Wai Canal, Pearl Harbor, Honolulu Harbor, Kaneohe Bay. This order conforms with progressively increasing mean count: 41.539, 42.372, 42.548, 42.639. However, the fiducial intervals of the means for all localities other than Ala Wai Canal overlap considerably. Therefore, they could have arisen in random sampling from one complex population.

The mean vertebral counts for localities on the other islands also could, with some speculation, be fitted into the above gradation. Certainly, in the absence of more precise information, Kawaihae Bay, with the highest mean count (42.743), would be placed at the opposite end of the series to Ala Wai Canal, as it is open to the sea and has only one or two very small streams flowing into it which are dry during part of the year. Again, however, there is no statistical evidence for the segregation of the mean counts of these other localities.

The lack of significant differences between the means for localities other than Ala Wai Canal is more clearly demonstrated in the analysis of variance which follows. In this, the Ala Wai Canal data have been omitted. It will be observed that there is no longer significant heterogeneity between localities:

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F
Islands	2	5.9321	2.9661	
Localities	3	15.0686	5.0229	1.50
Samples	8	26.8484	3.3560	9.78**
Individuals	2600	891.7377	0.3430	

** Highly significant; P is 0.01 or less.

In the foregoing analysis, an additional category—islands—has been incorporated. It will be observed that there are no significant differences between the means for islands (Table 2). In fact, the mean square for islands is considerably less than might have been anticipated. This may be due to the small number of localities which were sampled on islands other than Oahu. No conclusions as to whether or not the nehu of the various islands mix can be drawn from the analysis of the vertebral material.

DISCUSSION

The nehu is characteristically an inshore fish. For the most part, it is believed to occur only in certain isolated localities where the water is relatively more turbid and less saline than that of the open sea. As yet, it has not been seen at the outer edges of the reefs during numerous skin-diving expeditions, nor has it been taken by poisoning in these localities. However, the fact that the fish may be kept alive in the baitwells of vessels for several days in offshore waters shows that they can live, for a time at least, under ocean conditions. Moreover, there is one report of nehu having been seen in quantity outside the reef area. Mr. Lester Zukeran, a former fisherman and presently skipper of the University's research vessel *Salpa*, reports that, in the summer of 1940, large schools of nehu were present about a mile offshore, from Kaneohe Bay to Waimanalo on the windward shore of Oahu. They were so abundant that they interfered with fishing, the tuna failing to respond to the bait when it was thrown overboard. As the nehu were of large size, larger than those caught in Kaneohe Bay, the fishermen advanced the theory that they had migrated from Kihei, Maui, where large fish were commonly encountered. This is believed to be an unusual occurrence of nehu in outside waters. If it were common, it is reasonably certain that other reports would have come to our attention, for there are many tuna fishermen operating in outside waters during all months of the year. On the basis of this information, the hypothesis might be advanced that an essential, discrete population of nehu occurs in each separate baiting area, but with the provision that, on occasion, some mixing may occur between the stocks of the different areas.

The present analysis of vertebral data gives some support to this hypothesis, but not as much as might be desired for its adoption as a basis for regulation of the fishery. The existence of a separate population has been shown for one area only, Ala Wai Canal. For the others, the difference in mean vertebral count between localities could have arisen in random sampling from one statistically complex biological population. There is some indication of the presence of essentially separate units from the correspondence between the order of increasing mean counts for localities and the order of increasingly saline conditions within the localities, but the latter were estimated and not measured.

Although the hypothesis that essentially discrete units occur in each baiting area has not received a great deal of support from the analysis of vertebral material, it has not been disproved. More extensive sampling might demonstrate that there are small, but real, differences in mean count between localities and between islands, apart from the known heterogeneity between samples from one locality. Further evidence regarding the intermixture or isolation of populations, other than that of Ala Wai Canal, must await future investigations, preferably by some other method of study.

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On the Identity of *Stylarioides inflata* (Treadwell) and Its Extended Distribution (Annelida)[1]

OLGA HARTMAN[2]

THE IDENTITY of a common intertidal member of the family Flabelligeridae (polychaetous annelid) forms the basis of this report. The species is redescribed after a study of holotype specimens and other individuals from both adjacent and more distant regions. The characters of the prostomial and peristomial parts and the structure of transitional setae are detailed.

The materials were collected from widely scattered parts of the northeastern Pacific by numerous individuals. Holotypes and other specimens are deposited in the Allan Hancock Foundation of the University of Southern California. Illustrations were prepared by Anker Petersen, staff artist of the Allan Hancock Foundation.

Family FLABELLIGERIDAE St. Joseph, 1894
Genus STYLARIOIDES delle Chiaje, 1841
Stylarioides inflata (Treadwell)
Figs. 1*a–c*, 2*a–f*

Trophonia inflata Treadwell, 1914: 213–214, pl. 12, fig. 33.

Trophonia minuta Treadwell, 1914: 213, pl. 12, fig. 32.

Stylarioides dimissus Hartman, 1936: 21.

Stylarioides inflata Berkeley, 1941: 46.

MATERIALS EXAMINED

Holotype specimens of *Trophonia inflata* from Santa Catalina Island and others so reported (Treadwell, 1914) from Portuguese Bend and San Diego, California, in depths to 21–28 fm.; holotype specimen of *Trophonia minuta* from off La Jolla in 10 fm. Other collections come from Caspar, Mendocino County, shore; Moss Beach, San Mateo County, shore; off central California in 18–42 fm.; and along shaley coves of southern California, shore. The following station numbers of the *Velero III* (see Fraser, 1943, for data) are represented: 1191 (1), 1207 (1), 1210 (1), 1232 (5), 1260 (3), 1284 (2), 1417 (2), 1437 (2), 1456 (3), and 1468 (2), from shore to 39 fm., and including geographic areas from Oregon to Baja California, Mexico.

The type collections of *Trophonia minuta* and *T. inflata* have been compared and are considered to represent a single species. As *minuta* is preoccupied, the correct specific name is *inflata*, as used recently (1941) by Berkeley. *Stylarioides dimissus* Hartman, 1936, proposed to replace the preoccupied name, *minuta* Treadwell, 1914, is thus also synonymous.

The type specimen of *Trophonia inflata* from Santa Catalina Island has been dried at some time but the characteristic features of cephalic plaque and uncini are still visible. The specimen labeled *T. minuta* comes from a calcareous tube in sponge. Its anterior dorsal end is enlarged and obliquely truncate (Fig. 1*a*), covered with a thin layer of fine

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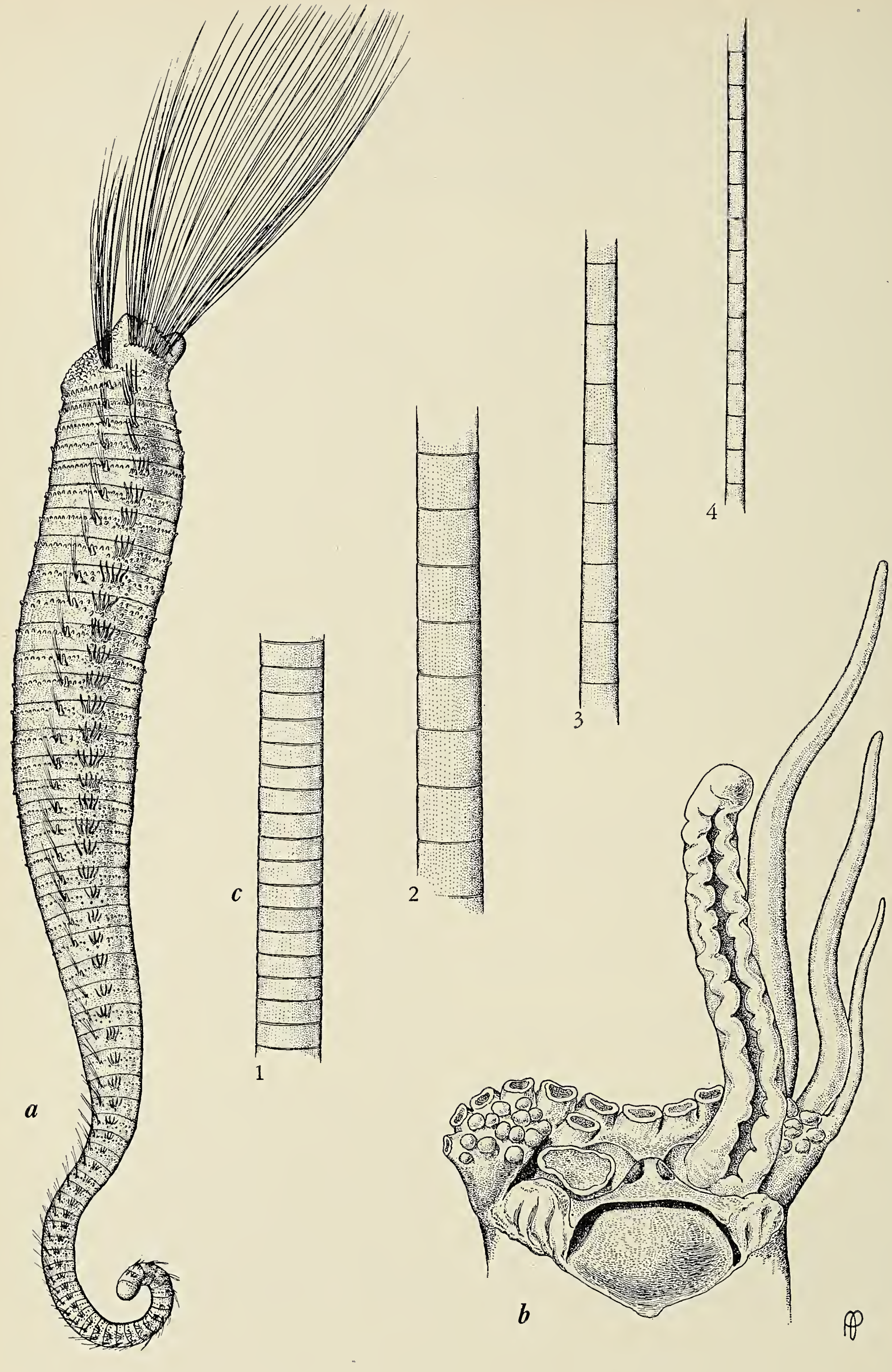
[1] Contribution No. 73 of the Allan Hancock Foundation of the University of Southern California, Los Angeles, California.

[2] Allan Hancock Foundation, University of Southern California. Manuscript received August 11, 1950.


4
3
2
c
1
a
b

sand grains. The first 2 setal fascicles are much the longest and strongest, and directed far forward to form a cephalic cage about the anterior end. The first neuropodial fascicle has about 12 long, slender, transversely barred setae; its notopodium is larger and more conspicuous. The second segment has shorter neuropodia and notopodia with setal fascicles similar to those in front but smaller. The third segment has more reduced setae than those in front; its notosetae number 6 to 8 in a fascicle; the neurosetae number 5 or 6 and, like those in front, are distally pointed. Thereafter, notosetae come to be inconspicuous and number only 3 or 4 in a bundle; this order is continued to the end of the body. From the fourth segment, the neurosetae are transitional between pointed setae and falcigerous uncini. The distal end is falcate and slightly to considerably thickened at the shoulder (Fig. 2*b*). A weak fracture, suggesting the articulation of a composite uncinus, is visible with favorable illumination; such uncini are present in segments 4 to 6 (Fig. 2*a–c*); in addition, an occasional transitional pointed seta can be found (Fig. 2*d*). From the seventh neuropodium, the typical simple hooks (Fig. 2*f*) are present and continued to the end of the body. They number 3 or 4 in a series or increase to 5 or 6 at segments 10 to 25, where the body is thickest. They are arranged in a single fan-shaped fascicle and are accompanied by very slender, hair-like, barred setae, located immediately in front of the uncini and alternating regularly with them.

The fifth segment has a pair of large nephridial apertures located just within the neurosetal fascicle and on the ventral side.

Based on various collections examined, the total number of segments ranges from 52 to 75; length of a larger specimen from southern California is 50 to 60 mm. (preserved). The body is thickest in the region of segments 20 to 25 and tapers to a narrow caudal end. The epithelial surface of the body is nearly smooth except for single rows of papillar fringe at the anterior end of the segment; this fringe extends around the body as a circlet and gradually diminishes in the posterior two thirds so as to be hardly visible.

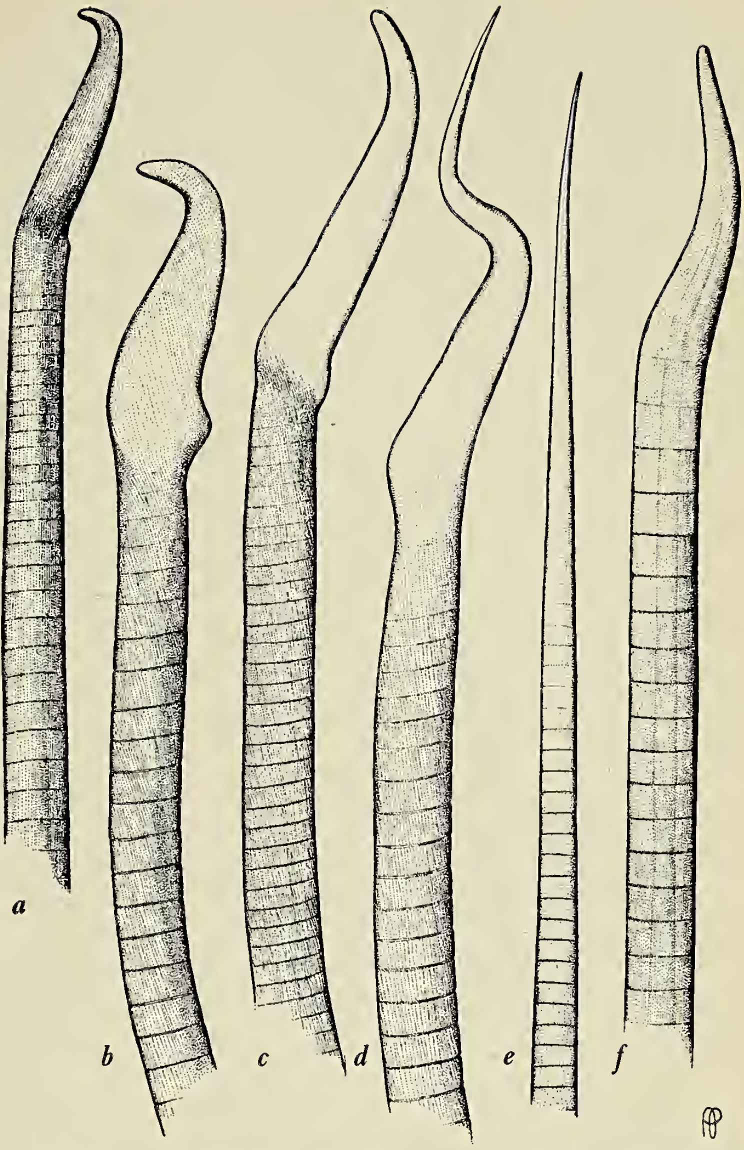


FIG. 2. *Stylarioides inflata*. *a*, Uncinus from fourth neuropodium, ×842; *b*, uncinus from fifth neuropodium, ×842; *c*, uncinus from sixth neuropodium, ×842; *d*, transitional uncinus from sixth neuropodium, ×842; *e*, notopodial seta from a median parapodium, ×482; *f*, neuropodial uncinus from a median parapodium, ×482.

The prostomium, to be seen only by dissection into the anterior end, is a small lobe with a pair of very large, nearly converging, dark, lenticulated eyes (Fig. 1*b*). The eyes are

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FIG. 1. *Stylarioides inflata*. *a*, Entire individual in right lateral view, ×4; *b*, anterior end seen from the front, right palpus and all except 3 tentacles cut off near the base, showing left palpus in place, prostomium with large eyes and oral slit, ×23.2; *c*, portions of a barred seta from the first segment: 1, near the base, 2, near the middle, 3, towards the tip, and 4, at the tip, ×162.

located on a prominent cone between the palpal bases. Palpi are paired, large, broad, deeply grooved, and intermediate in length between the larger and the smaller tentacles; they are inserted at the ventrolateral margins of the prostomium. The tentacles are of 2 sizes; on each side there are 6 larger dorsal ones in a crescentic arrangement and continuous with the corresponding ones from the opposite side; in addition there are about 13 smaller ones on a side, arranged within this crescent around the buccal region. All of the tentacles are long, cylindrical, and taper to blunt tips. The mouth is a broad, conspicuous crescent below the prostomial lobe and opens into a voluminous, pouch-like proboscis.

The burrow is long, U-shaped, larger at the cephalic end, and limited in diameter so that the contracted animal is closely surrounded; it is found in shale rocks or other penetrable materials such as sponge and shell masses.

DISTRIBUTION

Stylarioides inflata is common in low intertidal zones to 39 fathoms, in the warmer parts of the northeast Pacific, from Oregon south at least to Baja California, Mexico.

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Observations on a Specimen of Bluefin Tuna *(Thunnus thynnus)* Taken in Hawaiian Waters

FRED C. JUNE[1]

The bluefin tuna, *Thunnus thynnus* (Linné), has been reported from Hawaiian waters by several authors (Fowler, 1923 and 1928; Jordan and Evermann, 1926), however, it appears only rarely in the commercial tuna catches from this area. The last confirmed report of the occurrence of this species was a landing made by a commercial long-line boat off the coast of Waianae, Oahu, in 1939. There have been reports of bluefin tuna being taken along the Kona coast of the island of Hawaii, but they have been infrequent and the identifications were not validated.

On October 3, 1950, a specimen weighing 223 pounds was captured on long-line gear by the vessel *Ilima* while fishing off the southwest coast of Oahu, at approximately 21° 26′ N., 158° 27′ W. and at an estimated depth of 60 fathoms.

Measurements on this specimen were taken on October 6, 1950, at the Kyodo Fishing Co., Ltd., Honolulu, where the fish catch of the *Ilima* was unloaded for disposition. Viscera, for subsequent laboratory examination, were also obtained at this time. The various measurements, according to the methods described by Marr and Schaefer (1949), and meristic counts are given in Table 1 for the benefit of those interested in a critical study of the morphometric characters and distribution of this fish.

In all anatomical characters examined, this specimen agreed with Godsil and Holmberg's (1950) detailed description of the Pacific bluefin tuna, *Thunnus thynnus*. It also showed remarkable agreement with Kishinouye's (1923) description of *Thunnus orientalis*, except for the author's notation regarding the division of the ureter as it enters the kidney. Kishinouye (1923: 309) states, "In *Thunnus orientalis* the two ureters meet in a figure like U, and in other forms of the Japanese tunnies they meet like the figure V." In the Hawaiian specimen, the ureters met in a figure V at a point 31 mm. within the posterior margin of the kidney. The left branch continued anteriorly for a short distance, then diverged sharply, whereas the right branch curved outward gradually from the point of division. Both observations follow Godsil and Holmberg's findings for *T. thynnus*.

Another point of apparent difference between the description given by Godsil and Holmberg and that of Kishinouye concerns the branching of the coeliac-mesenteric artery. Kishinouye (1923: 378) indicates the presence of an abortive No. 1 branch in *T. orientalis*. He states, "In [the genus *Thunnus*] the first branch is abortive and nourishes the oesophagus only, or is entirely absent." Godsil and Holmberg (1950: 42) found no No. 1 branch in *T. thynnus* and conclude, "Occasionally a capillary-size vessel is present, originating approximately where the No. 1 branch should be, and like it running to the oesophagus. This vessel is so small, and is moreover one of several originating in this region and nourishing the adjacent tissues, that it was not considered homologous with No. 1 branch." There was no evidence of a

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[1] Pacific Oceanic Fishery Investigations, Honolulu, Hawaii. Manuscript received May 11, 1951.

No. 1 branch in the Hawaiian specimen, but inasmuch as the circulatory system was not injected, this blood vessel may have been overlooked.

The coloration of the finlets in the Hawaiian specimen differed from descriptions for this form given by other authors. Both the dorsal and anal finlets were bright yellow with broad black borders, similar to those of the big-eyed tuna, *Parathunnus sibi*. Kishinouye (1923: 439) notes that in *T. orientalis* the dorsal finlets are yellow, whereas the anal finlets are silvery; both are without a black margin. Godsil (1945: 187) states that in *T. thynnus* ". . . the finlets, though frequently yellow, are not edged with black." Roedel (1948: 60) similarly remarks that *T. thynnus* "lacks . . . the black edging of the finlets found on the yellowfin tuna when caught." These discrepancies may be simply individual color variations that exist within the species or real differences that show variation with geographical distribution.

Until a more detailed comparison is made between *T. thynnus* from the eastern Pacific and *T. orientalis* from the western Pacific, the specific standing of these forms remains in doubt.

TABLE 1

MEASUREMENTS* AND MERISTIC COUNTS OF A SPECIMEN OF *Thunnus thynnus* FROM HAWAIIAN WATERS

Measurements	
Total length	1740
Head length	497
Snout to insertion first dorsal	531
Snout to insertion second dorsal	950
Snout to insertion anal	1069
Snout to insertion ventral	540
Insertion ventrals to anterior edge vent	560
Greatest depth	450
Spread caudal	561
Length longest dorsal spine	189
Length first dorsal spine	189
Length second dorsal	268
Length anal	251
Length longest dorsal finlet	59
Diameter iris	44
Length maxillary	25
Least depth caudal peduncle	47
Greatest width caudal peduncle at keels	144
Meristic Counts	
First dorsal spines	14
Second dorsal rays	15
Dorsal finlets	8
Second dorsal plus dorsal finlets	23
Anal rays	15
Anal finlets	7
Anal plus anal finlets	22
Gill rakers (first gill arch)	12+24

* Measurements are in millimeters.

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News Notes

During the months of November, 1951, through February, 1952, a field party consisting of F. Stearns MacNeil, F. R. Fosberg, and Theodore Arnow, all of the U. S. Geological Survey, will conduct a scientific reconnaissance of a series of atolls in the northern part of the Marshall Archipelago. This project is a part of a co-operative program with the U. S. Corps of Army Engineers. The islands to be visited are Taongi, Bikar, Ailuk, Jemo, Utirik, Taka, Wotho, Likiep, Lae, Ujae, and Ujelang, with short stops at Kwajalein for refueling.

The objectives will be a co-ordinated study of the marine geology, marine ecology, land geology, hydrology, soils, vegetation, fauna, flora, and general ecology of these atolls. The work is a part of the Pacific Geologic Surveys program of the Military Geology Branch of the Survey and will be done in such a manner as to fit into the Atoll Research Program of the Pacific Science Board.

This expedition is of particular interest as several of the atolls to be visited have never been studied scientifically, and two of them, Taongi and Bikar, are reported to be only very slightly altered from their primeval state by human activity. It may be possible, from study of these islands, to gain some idea of the original condition of other similar atolls of the drier type, which are now greatly changed and almost entirely planted to coconuts.

The George Vanderbilt Pacific Equatorial Expedition of 1951 returned to Honolulu in September after a 3½-month cruise through the Hawaiian, Leeward, and Line Islands. Under the joint sponsorship of the Academy of Natural Sciences of Philadelphia and the California Academy of Sciences, the expedition obtained the largest fish collections as yet taken from the Leeward and Line Islands. Preliminary indications are that there will be many new records and species. The expedition was under the personal direction of George Vanderbilt who was assisted by E. S. Herald, California Academy of Sciences, V. E. Brock, Territorial Board of Agriculture and Forestry, and R. R. Harry, Natural History Museum, Stanford University, California.

A Committee on Hydrobiology was organized in Washington, D. C., on August 9, 1951, under the sponsorship of the American Institute of Biological Sciences. As its first task the committee will follow up its resolution that it would be desirable to have a directory of the facilities and personnel in marine and fresh-water hydrobiology in North America. The directory planned will be sufficiently detailed to be useful to beginning scientists as well as to research scholars and administrators in the field. A second and confidential report on the status of hydrobiological research today and that proposed for the immediate future will be compiled for use by the Office of Naval Research and other appropriate agencies.

Robert W. Hiatt, of the University of Hawaii, is chairman of this committee and editor of the proposed directory. Other members are: Arthur D. Hasler of the University of Wisconsin, Carl L. Hubbs of Scripps Institution of Oceanography, Daniel Merriman of the Bingham Institute of Oceanography, William E. Ricker of the Fisheries Research Board of Canada, and William R. Taylor of the University of Michigan.

The following publications of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, Tokyo, Japan, have been received. Each report includes a list of all the reports previously published, their distribution, and rules for obtaining them.

Reconnaissance Soil Survey of Japan, Northern Honshu Area, by Harry C. Mortlock. Report No. 110–G. June, 1951.

Reconnaissance Soil Survey of Japan, Hokkaido, by Thomas M. Bushnell and Thomas E. Ritchie. Report No. 110–H. August, 1951.

Safety in Japanese Coal Mines, by Major Charles S. Merriam. Report No. 140. January, 1951.

Japanese Mineral Resources, by Melvin Pollard. Report No. 141. March, 1951.

White Potatoes in Japan, by Ernest J. Wheeler. Report No. 142. May, 1951.

Japanese Crop and Livestock Statistics, 1878–1950, by Joseph C. Dodson and Clark C. Milligan. Report No. 143. June, 1951.

Sweet Potatoes in Japan, by Raymond E. Culbertson and James H. Boulware. Report No. 145. August, 1951.

Clam Culture in Japan, by A. R. Cahn. Report No. 146. September, 1951.

Properties and Uses of Commercially Important Japanese Woods, by H. D. Bruce, R. A. Cockrell, and Laurence J. Cummings. Report No. 147. October, 1951.

Agricultural Programs in Japan, 1945–51, compiled by Mark B. Williamson. Report No. 148. October, 1951.

Crop Insurance in Japan, by William H. Howe. Preliminary Study No. 58. July, 1951.

Management and Administration of Range Lands in Japan, by Walt L. Dutton. Preliminary Study No. 60.

Improved Forest Planting and Nursery Practices for Japan, by Floyd M. Cossitt. Preliminary Study No. 61. July, 1951.

Japanese Antarctic Whaling Expedition, 1950–51, Statistical Summary, by Benjamin Goldberg and Leland M. Lucas. Preliminary Study No. 62. July, 1951.

Beneficiation of Japanese Ores, by William E. Caldwell. Preliminary Study No. 63. August, 1951.

Policy and Program for Forest Research in Japan, by George W. Trayer. Preliminary Study No. 64. August, 1951.

Accounting and Auditing Methods of Japanese Agricultural Cooperatives, by John C. Essene. Preliminary Study No. 65. September, 1951.

Platinum Group Metals of Japan, by Melvin Pollard. Preliminary Study No. 66. September, 1951.

Pelagic Fur Seal Research off Japan in 1950, by Ford Wilke. Preliminary Study No. 67. October, 1951.

The University of Michigan Expedition to the Aleutian Islands has recently completed its fourth year of continuous anthropological and botanical work. The project is cosponsored by the Office of Naval Research and the Michigan Memorial Phoenix Project. Associated with the project have been A. C. Spaulding, J. F. Bank, W. R. Hurt, H. A. Miller, D. S. McClain, L. H. Jordal, and T. P. Bank II.

Investigations have been undertaken on more than 20 islands and in 5 Aleut villages. Major archeological excavations were completed at Agattu and Unalaska, and most of the known Aleut burial caves were visited and excavated below the levels previously sampled.

A number of interesting correlations between anthropological and botanical data have resulted. Phytoecological studies of prehistoric village sites indicate a close correlation between former Aleut plant uses and present-day vegetation and a possible correlation between the latter and age since abandonment of such sites. Ethnobotanical studies have shown the old Aleut plant lore to be more extensive and important to Aleut culture than has previously been supposed.

Aside from botanical and archaeological studies, the expeditions completed ethnological studies in the present-day villages. Medical and economic data are available for a close analysis of the trends of Aleut acculturation. Plant, animal, and place names fully annotated with actual Aleut names provide a basis for linguistic comparisons among the various Aleut dialects and between Aleut and Eskimo.

Research grants received recently at the University of Hawaii:

From Research Corporation, New York:
  Grant to Dr. Paul Scheuer, Chemistry, for research on the synthesis of a degradation product of strychnine.
  Grant to Dr. Carl Weatherbee, Chemistry, for research on the synthesis of 3-Aza-3-alkylbicycl (3,3,1) nonan-9-ones; a direct synthesis of products related to dibenamines.

From the United States Public Health Service:
  Grant in aid to Dr. G. W. Chu, Bacteriology and Zoology, for an investigation of the life history and epidemiology of a dermatitis-producing marine schistosome.

From Office of Naval Research:
  Research contract to Dr. R. W. Hiatt, Zoology, for research on methods of dispersing schools of fish.
  Research contract to Dr. W. A. Gosline, Zoology and Entomology, for an investigation of the nature of the fish faunas of the southern Marshall and Gilbert Islands.
  Research contract to I. M. Newell, Entomology, for research on the correlation of larvae and adults of the polytrichous trombidiform mites.

Dr. W. H. Peterson, of the Department of Biochemistry, University of Wisconsin, Madison, Wisconsin, spoke on "Production of Antibiotics and Their Use in Animal Nutrition" at a seminar convened on September 24 by the Hawaii chapter of Sigma Xi. Dr. and Mrs. Peterson were en route home from a 3-month Fulbright lectureship in Australia.

Dr. Claude ZoBell, of the Department of Microbiology, University of California, La Jolla, California, who was returning from several months with the Danish Deep-sea Expedition on the ship *Galatea*, spoke on October 25 to a seminar of marine biologists about some of the microbiological aspects of the expedition's investigations.

Sir Edward Mellanby of London, en route home from Australia, on October 17 addressed a meeting sponsored jointly by the local chapter of Sigma Xi and the Honolulu County Medical Society, on "Effect of Vitamins A and D on Bone and the Nervous System."

The Food and Agriculture Organization of the United Nations is providing assistance in various technological and biological aspects of fisheries research and development to many countries of the world, including Peru, Chile, Brazil, Pakistan, Ceylon, Haiti, and Thailand. Additional technical assistance agreements between FAO and other countries are being negotiated presently. These projects require the services of experts in many fields. Generally the tenure of the positions is 1 year, although it may be as short as 3 months. Persons interested in positions with the program are urged to write to the Fisheries Division, Food and Agriculture Organization of the United Nations, Vialle delle Terme di Caracalla, Rome, Italy.

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CRAWFORD, DAVID L. 1920*a.* New or interesting Psyllidae of the Pacific Coast (Homop.). *Ent. News* 31 (1): 12–14.

——— 1920*b.* Cerotrioza (Psyllidae, Homoptera). *Hawaii. Ent. Soc., Proc.* 4 (2): 374–375.

ROCK, JOSEPH F. 1916. The sandalwoods of Hawaii; a revision of the Hawaiian species of the genus *Santalum. Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry Bot. Bul.* 3: 1–43, 13 pls.

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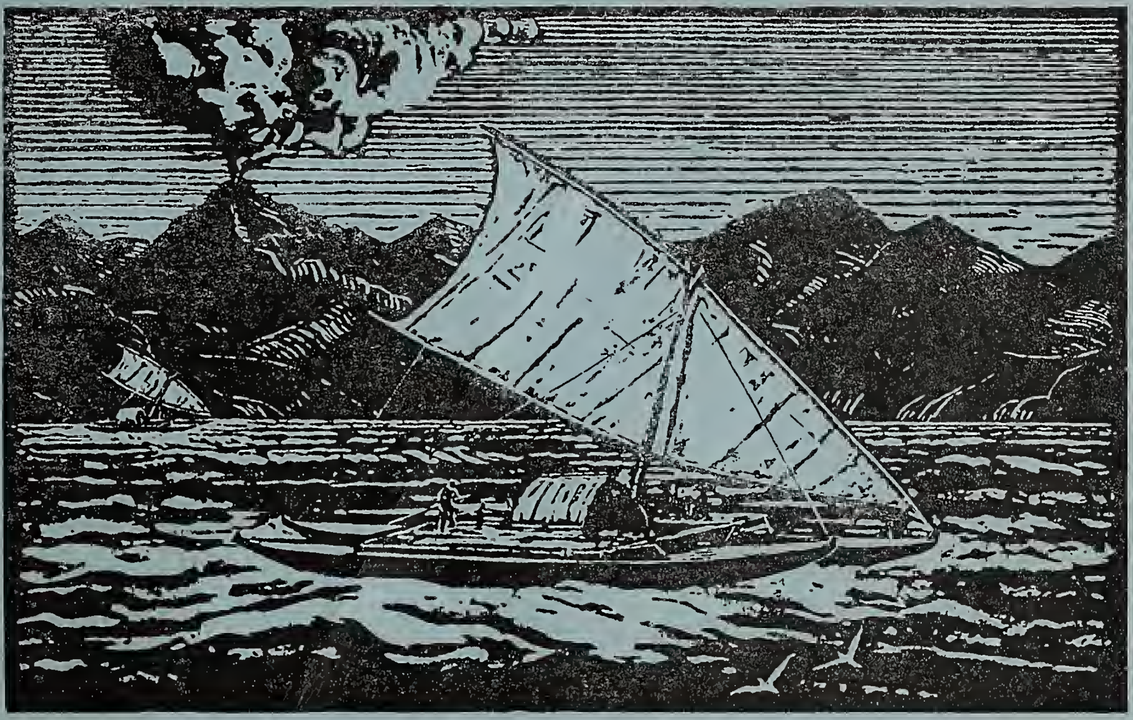
A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION



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MAY 6 1952

On the Psyllidae of New Zealand (Homoptera)[1]

L. D. TUTHILL[2]

INTRODUCTION

THE PSYLLID FAUNA of New Zealand has heretofore been only poorly known. It has been, therefore, a highly prized opportunity to spend a year in New Zealand collecting and studying this family of insects. It is obvious that one cannot hope to exhaust or even cover adequately the insect resources of an area of the size and diversity of New Zealand in one season, but enough was accomplished during that time to indicate the direction for further work and to give some idea of the relationships of the psyllid fauna of New Zealand to that of other areas.

Only two papers of significance on the Psyllidae of New Zealand have been published previously. These are Maskell's paper (1890) and that of Ferris and Klyver (1932). Maskell brought together his knowledge of the group in New Zealand and rectified some of the errors made in his earlier brief communications (Maskell, 1879, 1880). Portions of Maskell's material, which I have been able to study, consist of a few dried nymphs and one or two fragmentary adults in the collection at Cawthron Institute and three slides and a vial of dried nymphs in the Canterbury Museum. The paper of Ferris and Klyver was based on a collection of 450 specimens accumulated by Dr. J. G. Myers. They summarized all the earlier work and gave an adequate treatment of the 25 species which they had at hand. I have been able to collect and identify with reasonable certainty all but four of their species. Of the four, I have some question as to the identity of two; a third, probably a synonym, was not obtained; and the fourth, *Gyropsylla zealandica* (Ferris and Klyver), I was unable to locate. Two unexplained omissions from the paper of Ferris and Klyver are the lack of any indication of date for any of the material and the absence of any statement of size except for one species. As many of the New Zealand species appear to be very definitely seasonal, the collection data are quite important.

The bulk of the Myers collection, including all the types, was returned by Ferris and Klyver to Dr. Myers, who was killed in an accident shortly thereafter. As I have been unable to locate his collection, several uncertainties must remain until such time as its disposition can be ascertained and the specimens studied further, if they still exist. Thanks to the excellence of the illustrations, which are of the high standard usually produced by Ferris, few really serious obstacles were encountered.

In addition to the species recognized by Ferris and Klyver, I have obtained those of Maskell which they did not have, and I am adding 23 new species and 2 new genera to make a total of 51 species and 6 genera known from New Zealand. In this paper I have not repeated the descriptions or figures of those species which have been adequately described or figured previously.

All of the holotype and allotype specimens of the new species are deposited in the Cawthron Institute at Nelson. I feel very strongly that type material should be left in the country of origin if there is an institution within the country which can assure proper care of such material. It is in accord with this view that these types are left in New Zealand. Unfortunately this has been seldom done in the past. Therefore, present and future taxonomists in New Zealand face a tremendous difficulty.

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[2] Department of Zoology and Entomology, University of Hawaii.

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The number of those who have helped in one way or another in forwarding this work is very large, and space will not permit the complete listing of them here. My deepest appreciation is due Dr. E. A. Dennis and Mr. E. G. Budge of the U.S. Educational Foundation in New Zealand, who, from the time of the granting of the award until the completion of the work, have assisted in many ways. The administrative officers of Victoria University College and Massey Agricultural College, collectively and individually, have been most helpful. To Dr. J. H. Tetley of the Department of Zoology, Massey Agricultural College, who not only assisted me in collecting, but whose anticipation of my needs in equipment and materials and whose assistance in many ways have contributed greatly to my efforts, I am most deeply grateful. Of those many persons who have assisted in the field work, I must mention with gratitude Dr. W. Cottier of the Plant Diseases Division, D.S.I.R.; Mr. G. B. Rawlings, Forest Experiment Station, Whakarewarewa; Mr. L. J. Dumbleton, Mr. E. S. Gourlay, and Mr. A. W. Parrott, Cawthron Institute; Dr. R. A. Cumber, Phormium Research Station; Mr. R. R. Foster, Canterbury Museum; and Dr. T. E. Woodward, Auckland University College, all of whom contributed much valuable information as well as specimens. Dr. John Salmon of Victoria University College was most helpful prior to his departure for England. To Mr. John Carnahan and Dr. J. S. Yeates of the Department of Botany, Massey Agricultural College; Miss P. A. Lush, Dominion Museum; and Miss J. M. Dingley, Plant Diseases Division, D.S.I.R., I express sincere appreciation for assistance in identification of plants.

PROCEDURE

As the only material available for study in any of the collections in New Zealand has consisted of a few vials of specimens, mostly nymphs, and a few fragments of Maskell's material, it was necessary to collect the specimens for study. This is, of course, the ideal method, and it proved very pleasurable as well as fruitful. In making the collections, a heavy sweeping net and aspirator were used for capturing the adults and for general "prospecting." Once a population was located, an attempt was made to secure nymphs and to rear some of them to the adult state, thus making absolutely certain the identity of the host plant. In almost all cases, specimens of the host plant were taken and submitted to the botanists mentioned for identification.

Some specimens of each collection have been mounted on card points. All the specimens mentioned were collected by myself during the season 1950–51, except where otherwise stated.

For each species figured, specimens have been dissected, mounted in glycerin jelly, and examined under the dissecting and compound microscopes.

The terminology used is that in general use by workers on the Psyllidae with a few possible exceptions which are largely self-explanatory. I have used the term "points" to indicate the minute sclerotizations on the membrane of the wings as this is more accurate than the term punctations, which was used by Ferris and Klyver.

The names of localities in New Zealand have been taken from the maps of the New Zealand Automobile Association.

DISCUSSION

As is well known, the New Zealand flora shows many differences to the north or south of a line which falls approximately at the 38th parallel. Unfortunately, the time spent collecting in the northern section was rather too early in the season, and, on two of the three expeditions which I made into this area, the weather turned very bad; thus the representation from this area is rather poor. I am confident, therefore, that the number of species yet to be discovered in this area is quite large, especially as many of the plants which are restricted to this area are members of families or genera which are common hosts to psyllids elsewhere. The representation from the area south of this line is probably much better proportionately. Enough material was obtained there to indicate a large probable population on several groups of plants which are abundant in species and of which only a small percentage was examined. *Olearia* and *Senecio* are of particular interest in this regard. It appears that there are at least two distinct, parallel, evolutionary lines of psyllids on these plants and that they show a high degree of speciation and host specificity. One of these lines is represented by *Trioza subacuta*, *T. doryphora*, and *T. subvexa*, the other by *T. crinita* and *T. scobina*. As there are more than 80 species of plants belonging to these and related genera of Compositae in New Zealand, and as the majority of the 8 or 10 species which were examined yielded more than one species of psyllid, it seems probable that the psyllid fauna associated with this group is very large. It is certainly one of the most interesting from an evolutionary standpoint.

In the collecting, several remarkable examples of localization of infestations were encountered. The most extreme instance was that of *Trioza hebicola*, which was found on *Hebe salicifolia* at only one spot, although the host plant, which is very common throughout New Zealand, was examined throughout the season both before and after finding this one infestation.

Another instance of localized distribution is that of *Anomalopsylla insignita* n.g., n.sp., which was taken on *Shawia paniculata* at one spot near Nelson and obtained nowhere else. As this is one of the most common hedge plants in the country, it seems probable that this psyllid is permanently limited, ecologically, to such seaside areas as are little noticed. Just what the factors are which produce such localization is impossible to say until much more careful collecting has been done; theorizing at present would be futile although tempting.

No parasitized specimens of native species were noticed, but parasitized nymphs of some of the *Acacia*-inhabiting *Psylla* were seen. Predators of three groups were quite active throughout the country, the larvae of Coccinellidae, Hemerobiidae, and Syrphidae being common on infested plants. However, only one specimen of adult syrphid was obtained by rearing. The nomadic nature of my summer season largely precluded successful rearing of these voracious predators.

The relationship of the fauna of New Zealand to those of other parts of the world is of great interest, largely because of the relative present-day isolation of the islands. A few definite statements can be made now as regards the psyllid fauna. First, as has been mentioned previously by Heslop-Harrison (1949*b*), Ferris and Klyver were in error in stating that "There is no reason to suppose that any of them [the species they list from New Zealand] are introduced forms. . . ." Actually there is no doubt whatsoever that four of the five species which they assigned to *Psyllia* [*Psylla*] and one of their species of *Ctenarytaina* are introduced from Australia. These species of *Psylla* have recently been placed in a separate genus by Heslop-Harrison, together with several Australian species and one from India. In my opinion, although these species form a natural group, it is one which properly constitutes a subgenus. The remaining species assigned to *Psylla* by Ferris and Klyver (*P. apicalis*) and a new related species are of more doubtful affinities but are left in *Psylla* for the time being.

The genus *Ctenarytaina*, however, shows a definite link with Australia and also occurs in the Lau and Society Islands.

The new genus *Anomalopsylla* is most closely related to *Tainarys* of any known forms. On the basis of the peculiar wing venation alone, it could be assigned to the subfamily Ciriacreminae. However, as it differs widely from any known forms placed in that subfamily, and as I believe the presence of a cross vein or veins to have arisen separately a number of times in the family, it is placed tentatively in *Spondyliaspinae.* Both this genus and *Tainarys* seem to show some affinity to the distinctive Australian fauna. However, until the fauna of South America is much better known than it is at present, the degree of relationship between these genera and the Australian representatives of this subfamily is doubtful. Although I have seen no specimens of *Rhinocola aceris*, it would appear to be quite similar to *Tainarys* and *Anomalopsylla* in many ways, especially in the head structure and the lack of meracanthi.

The species *Atmetocranium myersi* seems to be a migrant from the tropical Pacific area.

If the species placed in *Metaphalara* [*Gyropsylla*] by Ferris and Klyver was properly assigned, this represents another link with the Americas, as the other known species of this genus are all American.

The dominant group present is the genus *Trioza*, which, being ubiquitous, furnishes little evidence for conclusions as to relationships with other faunas.

At present, then, it can be said that the demonstrated distributional relationships seem to be threefold, one group showing definite kinship to Australia, one to South America (one to both of these areas), and one to the tropical Pacific region. The first two would seem to argue for the often-postulated Antarctic connection of the lands south of 30°. Granting such a connection in the past, the area of origin and direction of migrations are still completely unanswered. There is, however, nothing to suggest New Zealand as the origin of any of the groups which are found there.

SYSTEMATIC TREATMENT OF NEW ZEALAND SPECIES

The species of Psyllidae now known from New Zealand represent four subfamilies, the Psyllinae, Triozinae, Pauropsyllinae, and Spondyliaspinae.

Keys to the species of the various genera are not included as it has been found impossible to prepare satisfactory keys without using genitalial characters predominantly, and I feel that such keys would have but little value.

KEY TO GENERA FOUND IN NEW ZEALAND

1. Basal vein of forewing branched trichotomously ....*Trioza*
   Basal vein of forewing branched dichotomously..................... 2
2. Vertex without coronal suture; proximal segment of metatarsi without claws.................*Atmetocranium*
   Vertex with coronal suture; proximal segment of metatarsi with one or two claws....................... 3
3. Genae more or less strongly produced as lobate processes............... 4
   Genae not at all produced........... 5
4. Mesotibiae with a longitudinal comb of short setae near apex....*Ctenarytaina*
   Mesotibiae without subapical comb of setae.........................*Psylla*
5. Metacoxae without meracanthus; forewing with extra branch on cubitus, cross vein between Rs and M_1..... ....*Anomalopsylla*
   Metacoxae with meracanthus; forewing with cubitus two-branched, without cross veins.................*Gyropsylla*

PSYLLINAE

This, the typical subfamily, is represented in New Zealand by two genera, *Psylla* and *Ctenarytaina.*

The species here placed in *Psylla* fall into two distinct groups. The first group of nine species (*P. acaciae* and related forms) are undoubtedly introduced from Australia, with one exception, and appear to be limited to their introduced host plants. The exception is *P. dodonaeae*, found abundantly on *Dodonaea viscosa*, a plant which has a very wide distribution in the tropical and warm temperate parts of the world. No psyllids have been recorded from it elsewhere, hence the status of this New Zealand species remains doubtful. It appears to be a natural migrant here, however, as there is no reason to believe that it was introduced by man. These species belong to the group which Heslop-Harrison recently treated as a distinct genus, *Acizzia*. In my opinion, although they constitute a natural group of species, they are not sufficiently distinct to warrant generic status and are more properly considered as a subgenus. The distinctive type of male proctiger of most of those known is the principal difference from the structure of typical *Psylla*, but this is not present in all the Australian forms. The tendency for the genal processes to cover the frons only incompletely is also not universal in the obviously related Australian species, nor is it limited to these Australian species, as several North American species exhibit the same trait. The prothoracic pleura vary in shape, and in some of the species, notably *acaciae-baileyanae*, they are of the form found in *Arytaina*. It is apparent that this character alone is insufficient for generic separation in the species here being considered, as they are obviously closely related forms. This seems to call for a reassessment of this and other characters used for generic separation in the entire subfamily. Fortunately, Heslop-Harrison has undertaken this difficult task.

The second group consists of endemic species, *P. apicalis* Ferris and Klyver and *P. carmichaeliae* n. sp. They are certainly not closely related to the introduced Australian species. *P. apicalis* appears to show relationship to *Euphalerus nidifex*, an American species. *P. carmichaeliae* is reminiscent of some of the North American species referred to *Arytaina*. For the present it seems best to place them in *Psylla* and avoid undue multiplication of genera or subgenera until the South American fauna is well known, when I believe their proper position can be ascertained.

The peculiar genus *Ctenarytaina* is known at present to contain three species from New Zealand, two from Australia, one from the Lau Islands, and one from the Society Islands. The attachment of the type species to *Fuchsia* makes the question of its occurrence in South America an interesting possibility. Although the female genital segment of some of the species resembles that of some Australian genera placed in the Spondyliaspinae, the genus is left in the Psyllinae for the present, principally on the basis of the presence of the meracanthi.

Genus PSYLLA Geoffroy

The use of *Psyllia* by Ferris and Klyver in accord with the opinion of E. P. Van Duzee is incorrect under the International Rules of Nomenclature; hence their species are here returned to *Psylla*. Five new species are added to the four previously known to occur in New Zealand.

Psylla (Acizzia) acaciae Maskell

1894 *Psylla acaciae* Maskell, Ent. Monthly Mag. 30: 171.

1932 *Psyllia acaciae* Ferris and Klyver, New Zeal. Inst., Trans. 63: 50, pls. 12, 13, 16.

This species has been adequately described and figured by Maskell and by Ferris and Klyver. It was taken from its host plant, *Acacia melanoxylon* R. Br., at Nelson, September 19, and at the Forest Research Station, Whakarewarewa, December 4 and March 25.

Psylla (Acizzia) conspicua n. sp.

Fig. 1

Length to tip of folded wings 2.75–3.25 mm.

COLOR: Body yellow to orange, abdomen green in female, dark brown dorsally and white ventrally in male. Forewings whitish, beautifully marked with brown (Fig. 1*a*).

STRUCTURE: Body surface finely punctate, nearly glabrous dorsally, venter sparsely pubescent. Head deflexed, wider than mesoscutum. Vertex short with shallow discal impressions, lateral ocelli on raised areas at posterior corners, anteriorly smoothly continuous with genae. Genae not touching but narrowly separated, produced as short blunt lobes, with prominent pubescence. Antennal sockets incomplete next eyes, antennae 1.6 times as long as width of head. Thorax broad, well arched. Pronotum long, rounding down anteriorly. Forewings about 2.5 times as long as wide, membrane somewhat thickened, thickly set with minute points; pterostigma long, narrow, Rs nearly straight, marginal cells large, cubital larger than medial. Hind wings large, 0.9 as long as forewings. Metatibia with basal spur, 1 outer and 4 inner apical spines. Proximal segment of metatarsi with 2 large, black claws.

Male proctiger short with large caudal lobe as figured. Forceps as long as proctiger in lateral view, curved caudad, tapering to blunt tip, small anterior lobe near base; in caudal view stout, straight to black incurved tips. Aedeagus a simple hook. Female genital segment large, shorter than rest of abdomen; dorsal valve long, nearly straight to blunt tip; ventral shorter than dorsal, sharp tipped.

HOLOTYPE, male, allotype, female, numerous paratypes, Houhora, October 3 and 4.

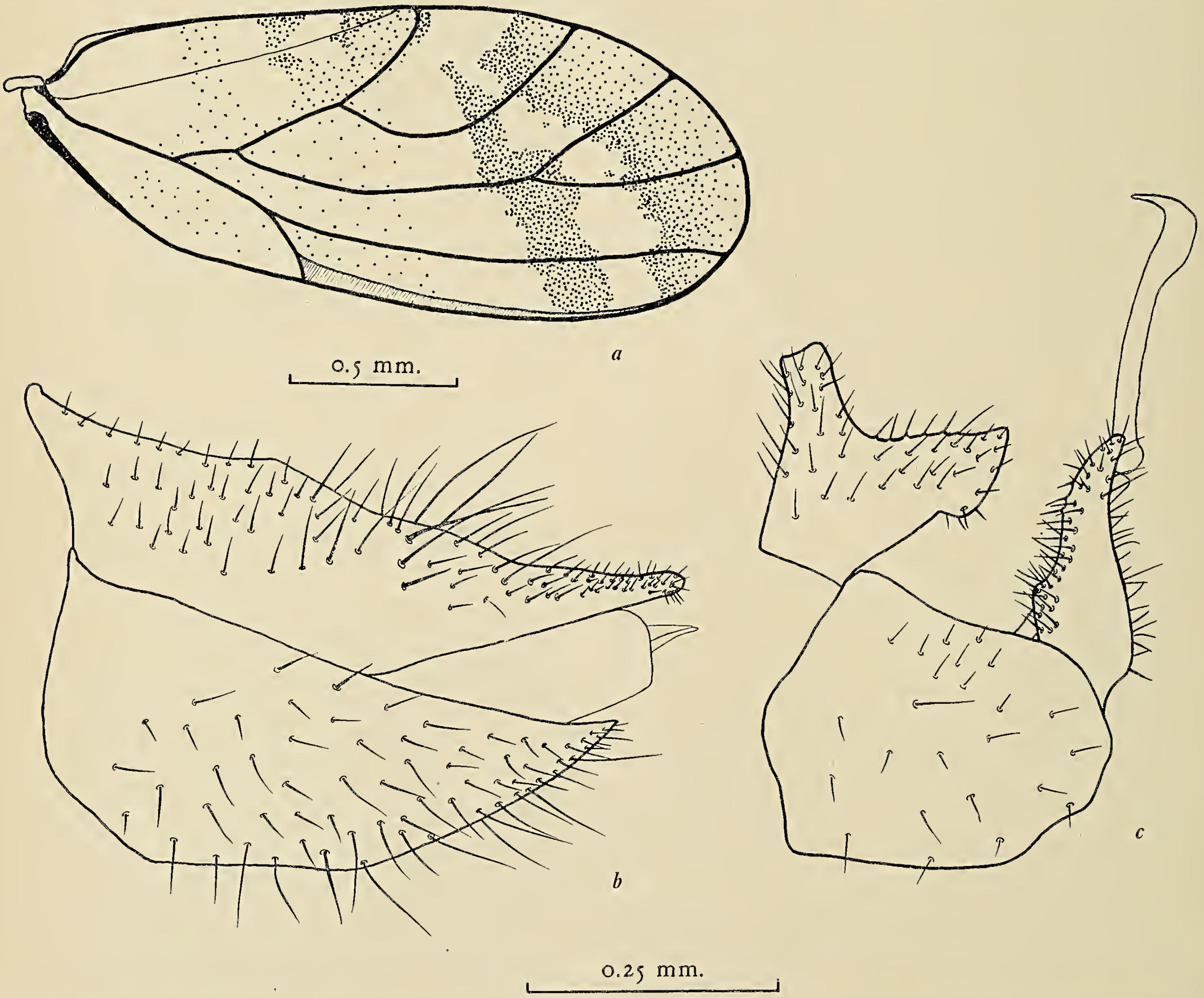

FIG. 1. *Psylla conspicua* n. sp. *a*, Forewing; *b*, lateral aspect of female cauda; *c*, lateral aspect of male cauda.

Several additional paratypes, Houhora, February 16, R. A. Cumber.

HOST PLANT: *Acacia melanoxylon* R. Br.

This strikingly marked species, which appears to be nearest *P. acaciae* of any of the species found in New Zealand, was teeming on the twigs of the host plant, in all stages of development, early in October.

Psylla (Acizzia) uncatoides (Ferris and Klyver)

1932 *Psyllia uncatoides* Ferris and Klyver, New Zeal. Inst., Trans. 63: 49, 53, pl. 13.

Length to tip of folded wings 2.0– 2.5 mm.

This appears to have the widest range of hosts of any of the species of *Psylla* known in New Zealand. It was taken in abundance on *Albizzia lophantha* at Otiria and New Plymouth, October 2 and 30, on an unknown species of *Acacia* at Whakarewarewa, December 4, and *Acacia verniciflua* at Palmerston North, February 15. It was originally described from specimens collected from *A. melanoxylon.*

The specimens on *Acacia* sp. from Whakarewarewa and, even more, those on *A. verniciflua* have the membrane of the forewings yellow. The marking of the forewings is variable in intensity as is the degree of marking on the dorsum.

Psylla (Acizzia) albizziae (Ferris and Klyver)

1932 *Psyllia albizziae* Ferris and Klyver, New Zeal. Inst., Trans. 63: 49, 51, pls. 12, 13.

Specimens identical with the original descriptions and figures were taken in great abundance and in all stages of development on *Acacia decurrens* wherever this widespread species was examined. Adults only were taken from *Clianthus puniceus.* No specimens were taken from *Albizzia lophantha*, only *P. uncatoides* being found on that plant.

HOST PLANTS: *Albizzia lophantha* Hook. [?], *Acacia decurrens* Willd., and possibly *Clianthus puniceus* Bks. & S.

Psylla (Acizzia) jucunda n. sp.

Fig. 2

Length to tip of folded wings 2.25–2.5 mm.

COLOR: General color variable from almost uniformly bluish green to yellow with olive-green markings and genae white. Forewings clear except for pigmented areas. Latter much as in *P. acaciae.*

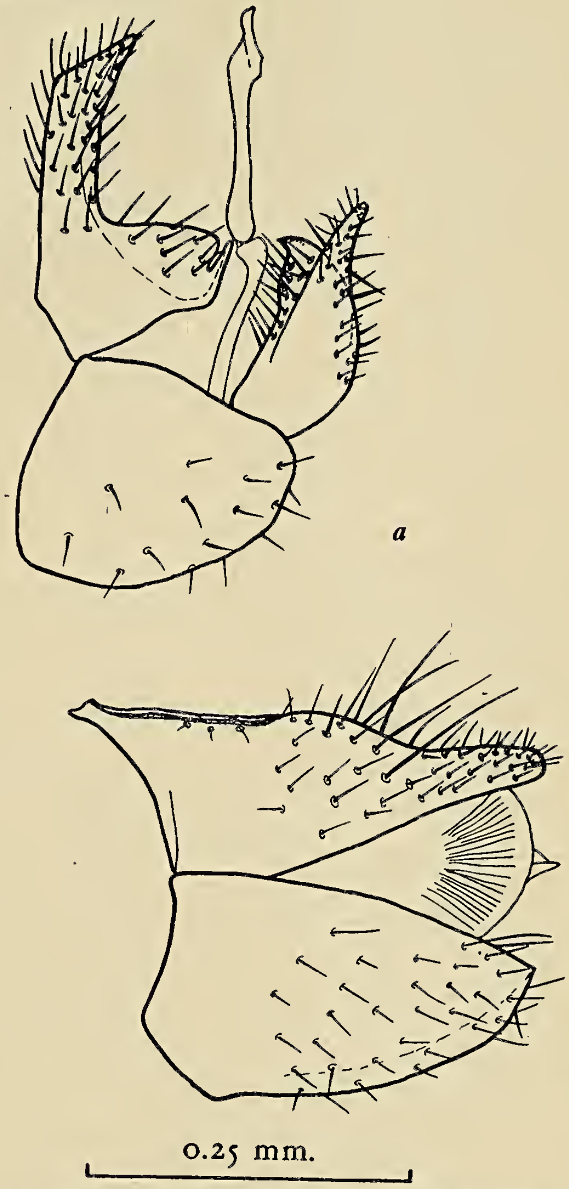

FIG. 2. *Psylla jucunda* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

STRUCTURE: Body surface finely punctate, very short sparse pubescence on dorsum, longer on venter. Head wider than mesoscutum. Vertex flat, with slight discal impressions. Genal processes somewhat depressed from plane of vertex, blunt, short, 0.4 as long as vertex (0.5 as long as medial suture), not touching. Frons visible between genal processes. Antennae twice as long as width of head. Eyes protruding. Thorax broad. Pronotum long, descending anteriorly. Propleura not equal. Forewings broadly rounded, 2.4 times as long as wide, membrane thickly set with minute points; pterostigma long and narrow, Rs nearly straight, marginal cells very large, nearly equal. Hind wings large, nearly reaching apex of forewings. Metatibiae with small basal spur, 5 apical spines, 1 on outer margin, 4 on inner margin. Proximal segment of metatarsi with 1 black claw on outer margin.

Male proctiger elongate, oblique apically, strongly produced caudad basally, caudal lobe with apical hook as figured. Forceps shorter than proctiger; in lateral view broad basally, almost evenly narrowed to blunt, black, incurved apex; large lobe arising on mesal surface, projecting anteriorly, sharp, black at tip; in caudal view stout, nearly straight to sharp black tips, black-margined mesal lobes touching, black tipped, sharp. Female genital segment shorter than rest of abdomen; dorsal valve slender apically, blunt; ventral valve very deep, blunt.

HOLOTYPE, male, allotype, female, numerous paratypes collected on *Acacia decurrens* in the Waitakere Hills near Auckland, September 29, additional paratypes from the same host at various localities and dates.

HOST PLANT: *Acacia decurrens* Willd.

This is the second most abundant of the three species of *Psylla* which were taken on this species of *Acacia*. It is a handsome, graceful little species with very distinctive male genitalia. Of the New Zealand forms, it seems to be nearest *P. uncatoides*.

Psylla (Acizzia) exquisita n. sp.

Fig. 3

Length to tip of folded wings 1.50–1.75 mm.

COLOR: Body white to yellow with some fuscous especially on legs and abdomen. Forewings white with three irregular, transverse black bands.

STRUCTURE: Body surface finely punctate, dorsum glabrous. Head wider than mesoscutum, scarcely deflexed. Vertex short, rounded down anteriorly, deeply excavate next eyes, lateral ocelli on large protuberances. Genae scarcely produced, not touching, large frons visible. Antennae far laterad, sockets almost touching eyes, 1.8 times as long as width of head. Eyes of moderate size, recessive, appearing somewhat stalked from shape of vertex. Pronotum long, sharply depressed anteriorly. Forewings broadly rounded, 2.5 times as long as wide; pterostigma large, Rs slightly sinuate, marginal cells large, equal, membrane somewhat thickened, very thickly set with minute points. Hind wings nearly equaling forewings, set with minute points.

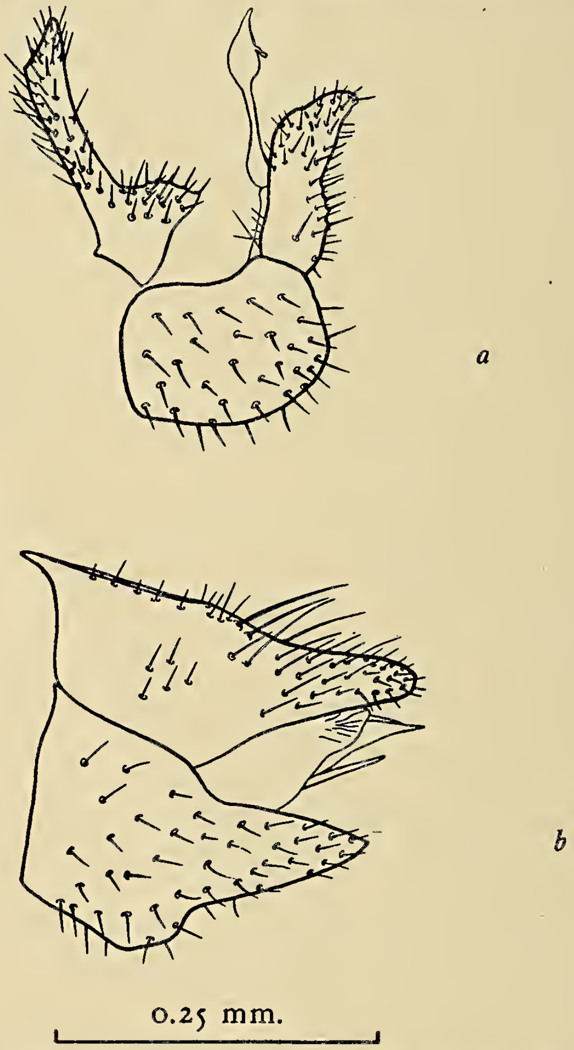

FIG. 3. *Psylla exquisita* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

Metatibiae with small basal spur, 1 outer and 4 inner, black, apical spines. Proximal segment of metatarsi with 1 black claw, outer.

Male proctiger long, slender, with basal caudal lobe. Forceps shorter than proctiger, somewhat sinuate, blunt, curved caudad apically, with small mesally projecting lobe on mesal surface (see Fig. 3*a*). Female genital segment short; dorsal valve straight, blunt; ventral valve with prominent hump, sharp.

HOLOTYPE, male, allotype, female, and several paratypes, Massey Agricultural College, October 27 and November 10, taken from *Acacia decurrens.* Additional paratypes from same host, Waitakere, September 29.

HOST PLANT: *Acacia decurrens* Willd.

This small, beautifully marked species is by far the least common of the three found on this species of wattle. It is very active and quite delicate, which makes the capture of intact specimens difficult.

Psylla (Acizzia) acaciae-baileyanae Froggatt

1901 *Psylla acaciae-baileyanae* Froggatt, Linn. Soc. N. S. Wales, Proc. 1901: 257, pls. 14, 16.

1924 *Arytaina acacia-baileyanae* Pettey, Union S. Africa, Dept. Agr., Ent. Mem. 2: 21, pl. 1.

1932 *Psyllia uncata* Ferris and Klyver, New Zeal. Inst., Trans. 63: 49, 53, pls. 12, 13.

Length to tip of folded wings 1.1–1.6 mm.

This minute species is abundant on *Acacia baileyana* and probably occurs wherever it grows in New Zealand. I have examined Froggatt's types and find them to be identical with *uncata* of Ferris and Klyver. It is unquestionably closely related to the other Australian species which inhabit the wattles in such abundance and is, therefore, necessarily kept in the genus *Psylla* even though the propleura are as in *Arytaina.*

In addition to those found on the ordinary host, I found it breeding in abundance on *Acacia podalyriaefolia* at Massey Agricultural College.

HOST PLANTS: *Acacia baileyana* F. v. M. and *A. podalyriaefolia* Cunn.

Psylla (Acizzia) hakeae n. sp.

Fig. 4

Length to tip of folded wings 2.0–2.25 mm.

COLOR: General color light reddish brown; genal processes, base of antennae, legs, and margins of some sclerites lighter; abdomen

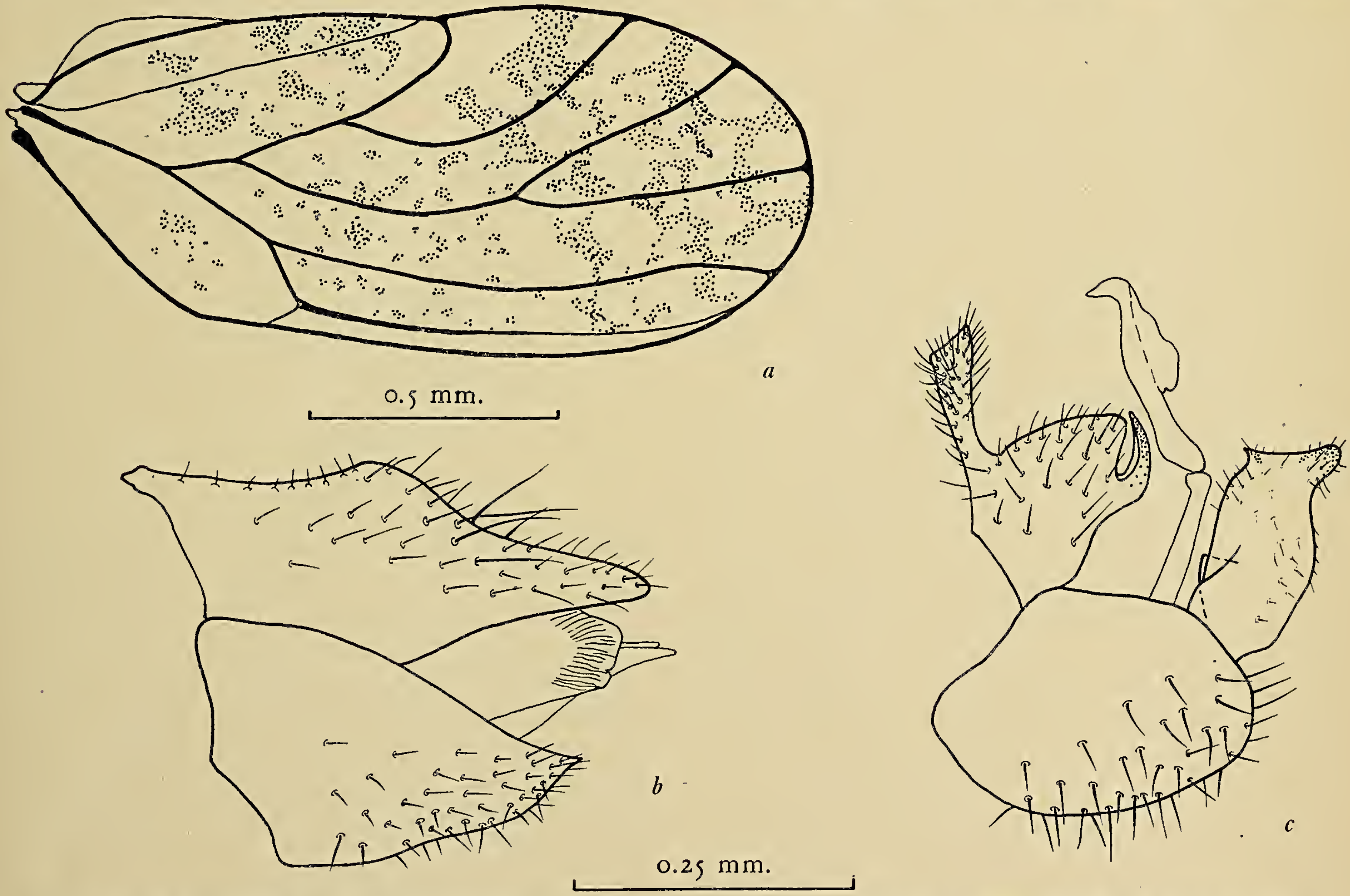

FIG. 4. *Psylla hakeae* n. sp. *a*, Forewing; *b*, lateral aspect of female cauda; *c*, lateral aspect of male cauda.

and venter of thorax more or less brown. Wing membranes white, forewings with dark brown maculations as figured.

STRUCTURE: Body surface punctate. Head and pronotum deflexed from plane of body. Head much wider than mesoscutum. Vertex strongly narrowed anteriorly, produced each side of median ocellus, emarginate next to eyes, with distinct discal impressions, lateral ocelli strongly raised at posterior corners. Genae produced as short, blunt, contiguous or slightly separated processes, covering frons, antennal sockets touching eyes. Antennae variable from less than 1.5 times as long as width of head to 1.6 as long. Eyes scarcely recessive, appearing somewhat stalked because of constriction around base. Pronotum large. Forewings broadly rounded, slightly over twice as long as wide, membrane thickly set with minute points; pterostigma long and narrow, marginal cells large, about equal. Hind wings with closely set minute points. Metatibiae with very small basal callus, 1 outer and 3 or 4 inner apical spines. Proximal segment of metatarsi with 1 outer black claw.

Male proctiger strongly produced caudad in basal half, terminating in large, heavily sclerotized hook, apical half slender, cylindrical, apex oblique. Forceps about as long as proctiger; in lateral view broad, margins sinuate, apex broadly emarginate, large anteromesal lobe, anterior corner of apex small, sharp, posterior produced as blunt lobe; in caudal view nearly straight to blunt black tips. Female genital segment shorter than rest of abdomen; dorsal valve elongate, blunt; ventral valve shorter, sharp.

HOLOTYPE, male, allotype, female, numerous paratypes from *Hakea acicularis*, Houhora, October 3. One additional paratype, Warkworth, October 1, and many from the same host near Tauranga, November 2.

HOST PLANT: *Hakea acicularis* R. Br.

Apparently introduced from Australia with the host plant, this small species was abundant on it at Houhora and Tauranga on the dates given. Keith L. Taylor of the Division of Entomology, in Canberra, Australia, has taken a closely related species from *Hakea dactyloides* in New South Wales.

Psylla (Acizzia) dodonaeae n. sp.

Fig. 5

Length to tip of folded wings 2.25–2.75 mm.

COLOR: General color of body white to pale buff, dorsum with orange and brown markings forming broken lines. Abdomen green. Forewings transparent, membrane slightly yellowish with light brown markings resembling the pattern of *P. acaciae* but much less distinct.

STRUCTURE: Body surface rough, shining. Dorsum with minute pubescence. Head and pronotum deflexed. Head wider than mesoscutum. Vertex plane with large discal impressions, narrowed anteriorly, produced above median ocellus, not as long as eyes laterally, lateral ocelli raised, at posterior corners. Genae produced as short cones, not quite touching basally, somewhat divergent, antennal sockets touching eyes. Antennae twice as long as width of head. Eyes not recessive, distinctly separated from vertex. Postocular sclerites well developed. Thorax moderately arched. Pronotum long, angular, and abruptly margined anteriorly. Forewings rounded apically, long, 2.75 times as long as wide, membrane thickly set with prominent points except along veins, fine alar radular areas; venation much as in *P. acaciae*, marginal cells larger. Hind wings long, 0.8 as long as forewings. Metatibiae with small basal spur, 1 outer and 3 inner apical spines. Proximal segment of metatarsi with 1 outer black claw.

Proctiger of male produced caudad basally, terminating in large, lightly sclerotized hook, apical half slender, cylindrical, curved caudad. Forceps shorter than proctiger; in lateral view broad basally, suddenly narrowed, then curved caudad to blunt black tips; in caudal view nearly straight to apical third, then

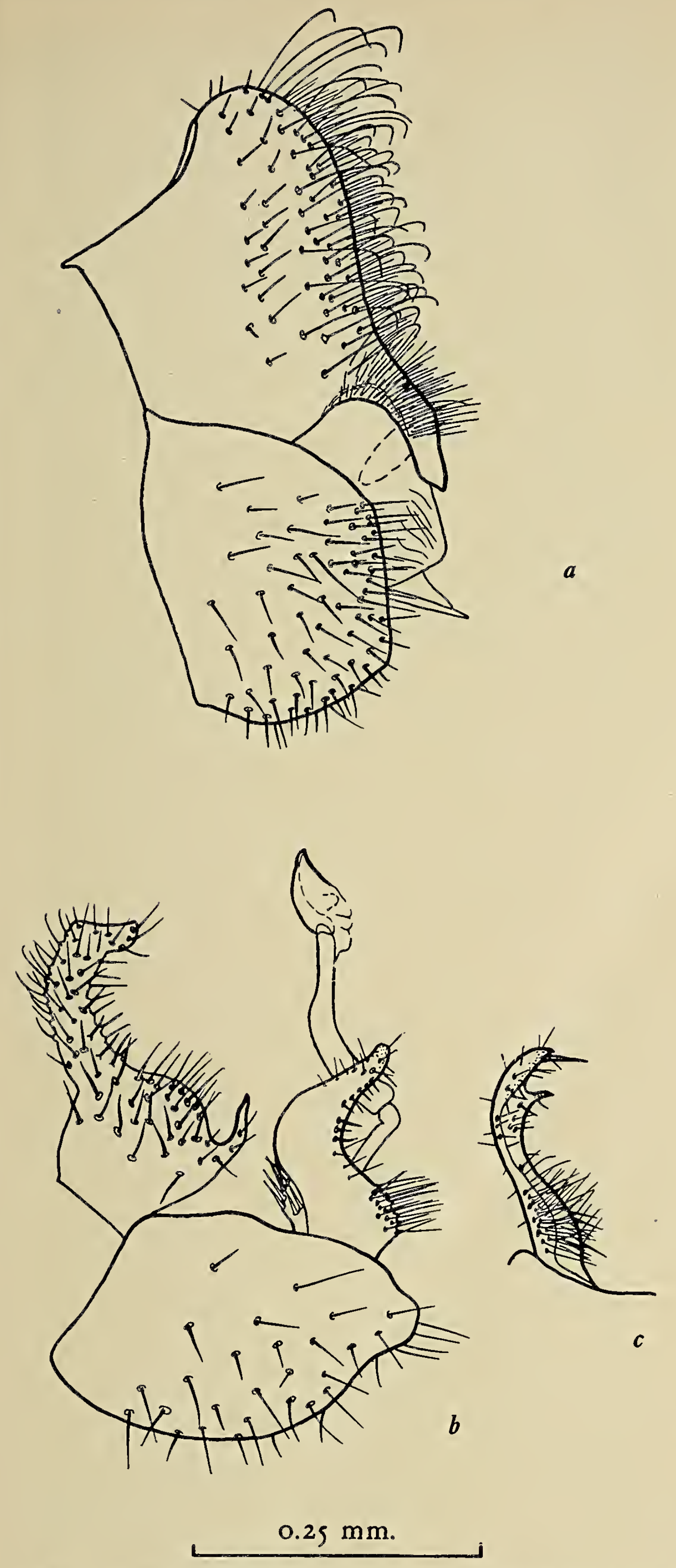

FIG. 5. *Psylla dodonaeae* n. sp. *a*, Lateral aspect of female cauda; *b*, lateral aspect of male cauda; *c*, caudal aspect of male clasper.

curved mesad to blunt tips, large, sharp, black-tipped tooth below apex. Aedeagus very heavily sclerotized, especially joint, structure as figured. Female genital segment very peculiar, large but much shorter than rest of abdomen; dorsal valve very strongly arched, swollen, caudal margin almost perpendicular to short, beak-like, heavily sclerotized tip, caudolateral margin with row of very long incurved setae; ventral valve very short, broadly truncate, with prominent inner "sleeve."

HOLOTYPE, male, allotype, female, taken from *Dodonaea viscosa* in the Forest Research Station grounds at Whakarewarewa, December 4. Numerous paratypes with same data and from same host near Nelson, September 19, January 16, and March 7.

HOST PLANT: *Dodonaea viscosa* Jacq.

Although taken only at two localities, this species certainly occurs throughout the New Zealand range of its host. As the host plant is very widespread outside New Zealand, its possible range elsewhere is very interesting.

The very peculiar female genital segment is unlike any other known to me except that of *Tetragonocephala flava* Crawford, a North American species.

Psylla apicalis (Ferris and Klyver)

1932 *Psyllia apicalis* Ferris and Klyver, New Zeal. Inst., Trans. 63: 49, 52, pls. 12, 13.

This handsome little species (2.0–2.25 mm.) was taken from Cape Rainga to Manapouri on its host, the kowhai, *Sophora tetraptera*. I cannot understand the statement of Ferris and Klyver that the head form is practically as in *Psylla acaciae* as it differs markedly, especially in the genal processes which are larger, contiguous basally for some distance, and are scarcely deflexed from the plane of the vertex. Also there are four large, evenly spaced black spines at the apex of the metatibiae in *apicalis* rather than the arrangement of 3 and 1 as in *acaciae*. Otherwise their description is quite adequate.

This species resembles *Euphalerus nidifex* Schwartz in appearance and, to some degree, in structure. It should, perhaps, be referred to that genus but is being left in *Psylla* for the time being in the hope that further collecting in Central and South America will give a more adequate concept of *Euphalerus* and thus allow a proper disposition of this and related New Zealand forms. The species which have been referred to *Euphalerus*, from the Oriental and Pacific areas, depart rather widely from the type species.

Psylla carmichaeliae n. sp.

Figs. 6, 7

Length to tip of folded wings 2.5–3.0 mm.

COLOR: General color tan (greenish in some specimens) with irregular fuscous markings, more or less of linear pattern on dorsum. Abdomen brown. Forewings white with dark brown spots as figured.

STRUCTURE: Body surface punctate, shining. Head as wide as mesoscutum. Head and pronotum deflexed at about 45° from plane of body. Vertex nearly twice as wide as long, with large, deep discal foveae, slightly raised above median ocellus, next antennal sockets smoothly continuous with genae. Genae produced as large, stout processes, almost as long as vertex, contiguous basally, with numerous prominent setae, also with small lobe next eye, below antennal socket. Antennae slightly less than twice as long as width of head. Eyes of medium size, slightly recessive. Pronotum large, on same plane as vertex. Forewings broadly rounded, slightly over twice as long as wide, membrane thickened, translucent, punctate, thickly set with small points, veins prominent, raised; pterostigma small, narrow, Rs nearly straight to near apex then curved to margin, medial cell small, cubital large, very broad. Hind wings nearly equaling forewings, very thickly set with minute points. Metatibiae without basal armature, 5 large, black, apical spines. Proximal segment of metatarsi with two black claws. Meracanthi unusually large.

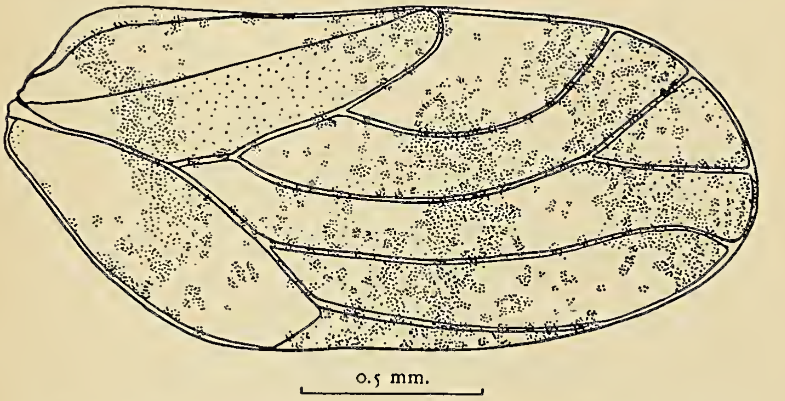

FIG. 6. Forewing of *Psylla carmichaeliae* n. sp.

Male proctiger long, swollen caudad. Forceps shorter than proctiger; in lateral view broad basally, almost evenly tapered to black blunt tip, curved mesad and caudad; in caudal view broadly touching basally then nearly straight to incurved black tips. Aedeagus quite simple, as figured. Female genital

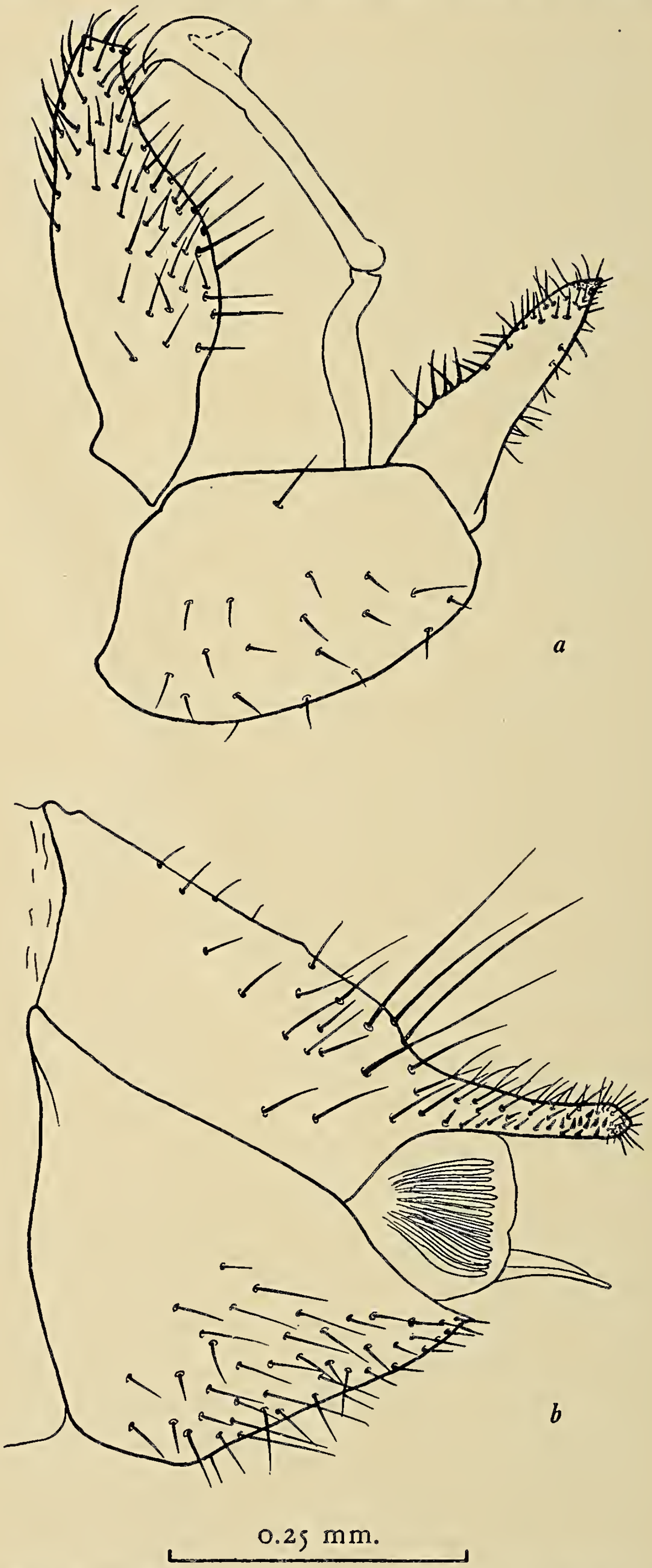

FIG. 7. *Psylla carmichaeliae* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

segment large; dorsal valve somewhat attenuate in apical portion, apex rounded, upturned; ventral valve shorter than dorsal, sharp.

HOLOTYPE, female, allotype, male, numerous paratypes, Crown Range, December 6, 1950, E. S. Gourlay, beaten from *Carmichaelia* sp. Two additional paratypes taken from *Carmichaelia* sp., near Kingston, January 22.

HOST PLANT: *Carmichaelia* sp.

The degree of relationship of this form to that here designated as a subspecies is a puzzle. Whether intensive future work will show them to be distinct species or whether they will prove to be merely two of a large number of variants in a complex, inhabiting the various species of *Carmichaelia*, is problematical but I suspect it will prove to be an inseparable complex.

Psylla carmichaeliae indistincta n. subsp.

Fig. 8

Length to tip of folded wings 2.3–2.5 mm.

COLOR: General color orange-brown to yellow-brown. Vertex and pronotum mostly white with fuscous markings. Dorsum of thorax with fuscous and white longitudinal stripes. Femora and abdomen dark brown. Forewings white with dark brown spots as in typical subspecies but more concentrated.

STRUCTURE: Body surface punctate, shining. Head as wide as mesoscutum. Head and pronotum deflexed. Vertex with strong discal impressions, produced anteriorly, somewhat overhanging median ocellus, 0.6 as long as wide. Genae produced as large blunt processes, not contiguous at base but touching for about half their length, sharply depressed below plane of vertex, 0.6 as long as vertex, small projecting lobe next to eye. Antennae twice as long as width of head. Eyes small, not recessive. Pronotum wide, in same plane as vertex. Forewings twice as long as wide, broadly rounded, membrane thickened, translucent, punctate, thickly set with points; pterostigma present, short and broad, Rs long, straight to near tip then curved to margin, medial cell small, cubital much larger, short and broad. Metatibiae without basal armature, with 5 black apical spines. Proximal segment of metatarsi with a pair of black claws. Meracanthi large.

Male proctiger long, swollen caudad. Forceps shorter than proctiger; in lateral view broad basally, narrowed to sharp tip, margins somewhat sinuate; in caudal view stout,

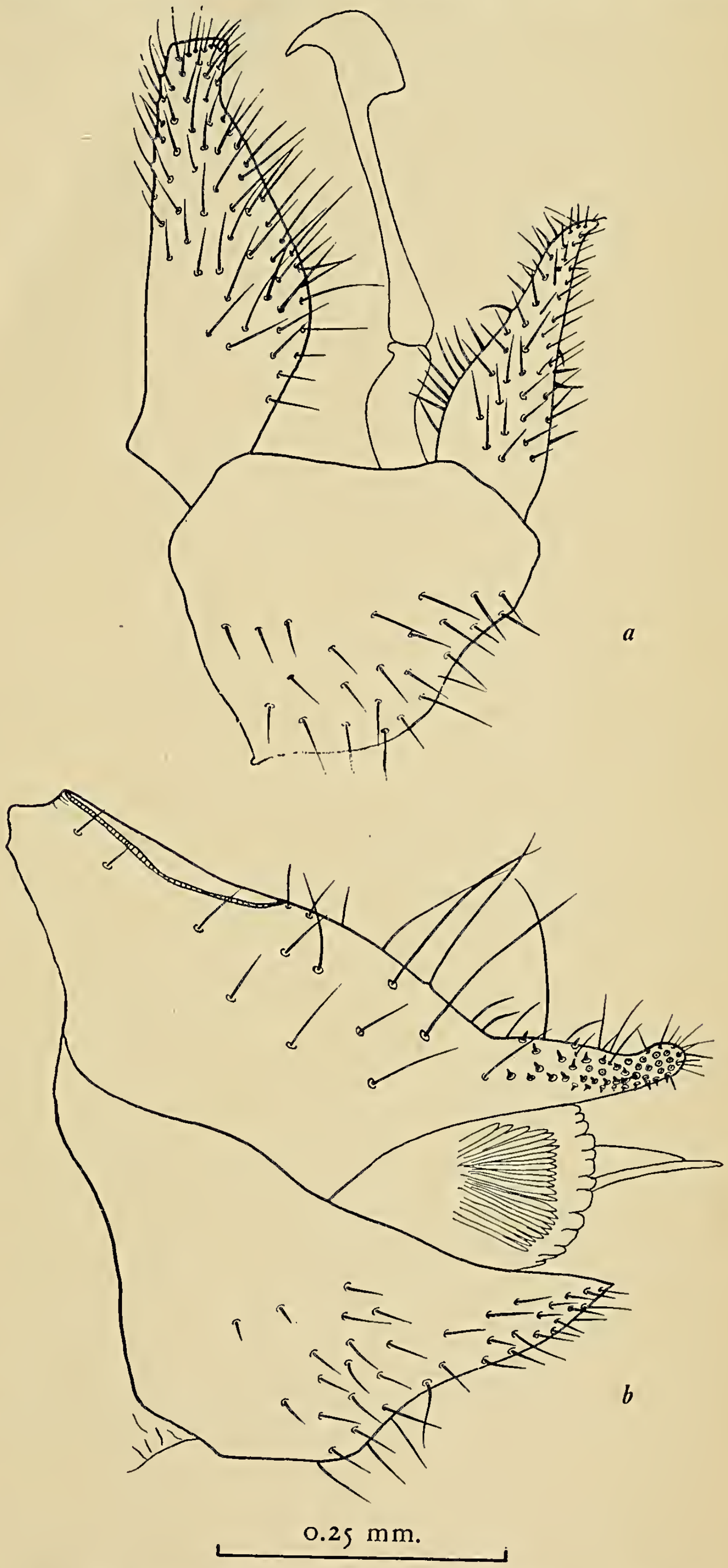

FIG. 8. *Psylla carmichaeliae indistincta* n. subsp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

broadly touching basally, nearly straight, tapering to black incurved tips. Aedeagus rather simple, as figured. Female genital segment large; dorsal valve attenuate apically, blunt; ventral valve shorter than dorsal, deep, sharp apically.

HOLOTYPE, female, allotype, male, numerous paratypes, Fox Glacier, February 7, taken on *Carmichaelia* sp. One specimen taken at Brown's Creek, Rai Valley, January 17, differs in having the forewing almost entirely dark, a narrower, longer pterostigma, somewhat shorter antennae.

HOST PLANT: *Carmichaelia* spp.

The large series of specimens at hand seems to be consistently different from the form taken east of the mountains. The chief differences are the size, the length of the vertex and the nature of its anterior margin, the position, shape, and size of the genal processes, the width of the pterostigma, the straight or upturned tip of the dorsal valve of the female genital segment, and the color, especially the degree of pigmentation of the wing.

This form has a marked resemblance in general appearance to *Arytaina robusta* Crawford of western North America.

Genus CTENARYTAINA Ferris and Klyver

1942 *Papiana* Tuthill, Bernice P. Bishop Mus., Occas. Papers 17: 78.

This genus was erected by Ferris and Klyver for *Rhinocola fuchsiae* Maskell and three other related species. They surmised correctly that *Rhinocola eucalypti* Maskell belonged to the same genus, but as they had no specimens they did not place it there. Although this was the genus *Rhinocola* of Maskell it does not encompass those Australian species assigned to *Rhinocola* by Froggatt. Of the five species known from New Zealand three are apparently endemic and two are undoubtedly introduced.

The genus *Papiana*, which I erected for a species from the Society Islands, is identical with *Ctenarytaina*. The two species which have been assigned to *Papiana*, *P. lulla* (Society Islands) and *P. distincta* (Lau Islands), extend the range of the genus well into Polynesia.

Ctenarytaina fuchsiae (Maskell)

1890 *Rhinocola fuchsiae* Maskell, New Zeal. Inst., Trans. 22: 162, pl. 12.

1932 *Ctenarytaina fuchsiae* Ferris and Klyver, New Zeal. Inst., Trans. 63: 55, pl. 14.

Length to tip of folded wings 1.6–2.1 mm.

This species has been well described by Maskell and by Ferris and Klyver. It is found throughout New Zealand on *Fuchsia* spp. from the time of the first opening of the leaf buds in the spring until past midsummer. I was unable to find living adults after the third week in January. Although it occurs on the host in myriads there is no evident injury.

HOST PLANTS: *Fuchsia excorticata* Linn., *F. procumbens* Hook.

Ctenarytaina clavata Ferris and Klyver

1932 *Ctenarytaina clavata* Ferris and Klyver, New Zeal. Inst., Trans. 63: 55, 57, pl. 14.

Length to tip of folded wings 1.3–1.5 mm.

I found this minute species to be present on both *Leptospermum scoparium* and *L. ericoides* at many localities throughout New Zealand. The abundance varied considerably but, without exception, at least a few adults could be obtained by sweeping the hosts when they were in bloom.

HOST PLANTS: *Leptospermum scoparium* Forst. and *L. ericoides* A. Rich.

Ctenarytaina pollicaris Ferris and Klyver

1932 *Ctenarytaina pollicaris* Ferris and Klyver, New Zeal. Inst., Trans. 63: 55, 57, pl. 14.

I made only one collection of this form although I swept its host plant throughout New Zealand. I obtained a few specimens at Okuti Valley on the Banks Peninsula, January 19, swept from *Leptospermum ericoides* in company with *C. clavata*. A few specimens are also at hand collected at Foxton, January 20, 1951, by R. A. Cumber.

HOST PLANT: *Leptospermum ericoides* A. Rich.

The comparative rarity of this species during the season 1950–51 must be unusual. Otherwise, it would be unable to maintain itself in competition with *clavata*.

Ctenarytaina thysanura Ferris and Klyver

1932 *Ctenarytaina thysanura* Ferris and Klyver, New Zeal. Inst., Trans. 63: 55, 56, pls. 14, 16.

Length to tip of folded wings 1.25 mm.

I did not collect any specimens of this minute species, but specimens were made available to me by Woodward, Cottier, and Miller. It apparently is quite common on its host throughout New Zealand.

HOST PLANT: *Boronia* sp.

Ctenarytaina eucalypti (Maskell)

Fig. 9

1890 *Rhinocola eucalypti* Maskell, New Zeal. Inst., Trans. 22: 160.

Length to tip of folded wings 1.5–2.0 mm.

Maskell's extended description of this species is quite good. Additional data are: Antennae 1.3 times as long as width of head. Metatibiae with 5 short black apical spines. Proximal segment of metatarsi with 2 black claws.

Many specimens in all stages of development were taken at several localities on both North and South Islands, including Tauranga, Palmerston North, and Ashburton. They appear to occur only on the young growth, the first specimens being taken in October.

HOST PLANT: *Eucalyptus globulus* Labill.

This species was also taken on *Eucalyptus bicostata* in Canberra, Australia.

TRIOZINAE

A single ubiquitous genus, *Trioza*, represents this subfamily in New Zealand.

The well-developed radular areas on the forewings, alar radulae, which are so typical of this subfamily, are very strongly developed in many of the New Zealand species. The function of these structures is unknown but the presence of a raised area on the marginal vein at the base of the radula on many of these species suggests that they are stridulatory. As many of the species can be observed to rub their wings slightly when alive this seems more probable.

Genus TRIOZA Förster

1879 *Powellia* Maskell, New Zeal. Inst., Trans. 11: 223.

In his 1880 paper on Coccidae, Maskell transferred his genus *Powellia*, which he established on nymphal material, from the

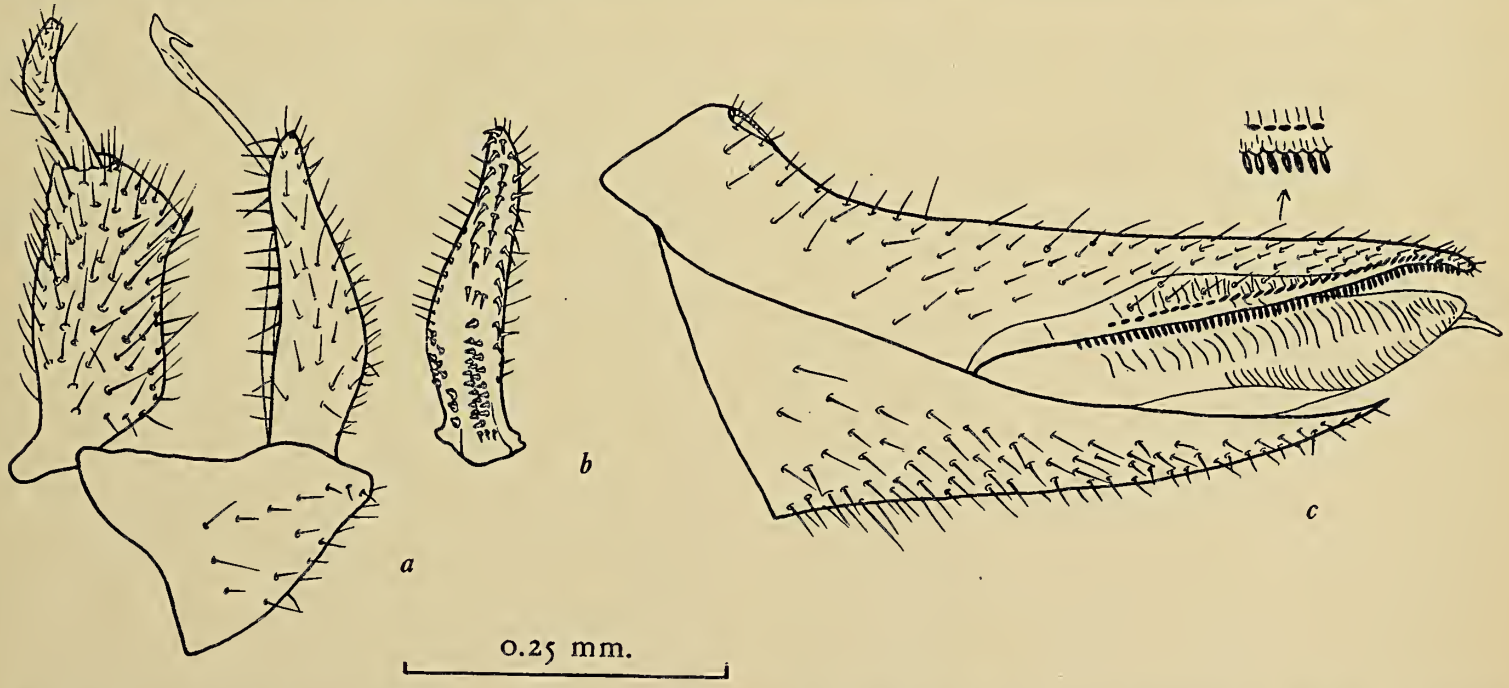

FIG. 9. *Ctenarytaina eucalypti* (Maskell). *a*, Lateral aspect of male cauda; *b*, inner aspect of clasper; *c*, lateral aspect of female cauda.

Coccidae to the Aleyrodidae. Subsequently he obtained adults, realized his error, and in his paper on the Psyllidae in New Zealand (1890) he synonymized *Powellia* with *Trioza*. Ferris and Klyver, however, considered that the New Zealand species constituted a separate genus and therefore resurrected *Powellia*. The bases of their distinction were the presence of serrations of greater or lesser prominence on the base of the metatibia and the position of the large spines at its apex. These are not limited to the New Zealand forms nor are they, in my opinion, sufficient reasons for maintaining a separate genus.

The genus *Trioza* is one of the largest, perhaps the largest, genus in the family. The forms found in New Zealand show considerable diversity. With one exception (*T. adventicia* n. sp.), they are limited to endemic hosts and are undoubtedly endemic species. A very large number of species appears to have developed on the native Compositae, principally the shrubby ones. This is a family of plants which is not known to support many species of psyllids in other parts of the world.

Trioza vitreoradiata (Maskell)

1879 *Powellia vitreo-radiata* Maskell, New Zeal. Inst., Trans. 11: 223, pl. 8, fig. 22.
1890 *Trioza pellucida* Maskell, New Zeal. Inst., Trans. 22: 164, pl. 11.
1903 *Trioza alexina* Marriner, New Zeal. Inst., Trans. 35: 305, pls. 33, 34.
1932 *Powellia vitreoradiata* Ferris and Klyver, New Zeal. Inst., Trans. 63: 39, 42, pls. 7, 8, 16.

Large numbers of this species were taken throughout New Zealand on various species of *Pittosporum*, throughout the season, for I suspected that there were probably different species present on the different members of the host genus. After very careful examination of many specimens from many localities, from Spirit's Bay to Oban, and from at least four species of *Pittosporum*, I am convinced that there is but one species of psyllid present. Minor variations in structure are present, of course, but none that seems significant or that is constant. The sclerotic points on the membrane of the forewing, for example, range from very prominent points over all the membrane to complete absence except in the extreme base, with a great range of intensity and a considerable range in size. There is no correlation with season, locality, or host plant.

I can add nothing to the very complete description given by Ferris and Klyver except that the size range is 3.25 to 4 mm. and that the color variation is even greater than they stated, ranging to almost entirely black except for the thoracic pleura and the edges of the abdominal tergites.

HOST PLANTS: *Pittosporum* spp., i.e., *P. eugenioides*, *P. tenuifolium*, *P. crassifolium*, *P. colensoi*.

Maskell recorded it as also occurring on *Discaria toumatou* and *Geniostoma ligustrifolium*. Two species, both here described as new, have been taken from *Discaria toumatou*. The male of the more common one, *Trioza discariae* n. sp., is almost certainly the source of Maskell's drawing of the male which Ferris and Klyver were at a loss to explain, resorting to an assumption of remarkable error on the part of Maskell. I have been unable to find any psyllid associated with *Geniostoma* but am confident that when it is rediscovered it will prove to be a distinct species.

In addition to the specimens collected by myself, I have had for study material from the various collections in New Zealand. These are from several other localities and from several species of *Pittosporum*.

Trioza discariae n. sp.

Fig. 10

1879 *Powellia vitreoradiata* Maskell (in part), New Zeal. Inst., Trans. 11: 223.
1890 *Trioza pellucida* Maskell (in part), New Zeal. Inst., Trans. 22: 164, pl. 11.

Length to tip of folded wings 2.25–2.5 mm.

COLOR: General color of head and thorax tan with dark brown markings. Abdomen dark brown. Wings hyaline.

STRUCTURE: Body surface finely punctate, with moderate pubescence, more or less dusted with powdery wax. Head wider than mesoscutum. Vertex strongly impressed discally, slightly produced anteriorly. Genal processes large, conical, acute, divergent, 0.66 as long as vertex. Eyes large, hemispherical. Postocular areas large. Antennae slightly less than twice as long as width of head. Pronotum depressed slightly below plane of vertex. Forewings rounded apically, 2.66 times as long as wide, membrane with points in small area at base and along claval suture; veins prominently setate, Rs of moderate length, slightly sinuate, marginal cells nearly equal. Hind wings with prominent points on membrane, venation unusually distinct. Metatibiae with serrate basal carina, 1 outer and 3 inner apical spines.

Male proctiger short, broadly produced caudad. Forceps shorter than proctiger; in lateral view broad with two broad lobes on anterior margin, lower one arising from mesal surface, blunt, black tooth apically; in caudal view stout, with large, sharp, black tooth near apex on inner margin; in dorsal view with two large, sharp, black teeth projecting inward, anterior one somewhat below other, inner surface with many long setae. Female genital segment short, dorsal valve excavate below anus, downcurved to blunt apex; ventral valve shorter than dorsal, sharp.

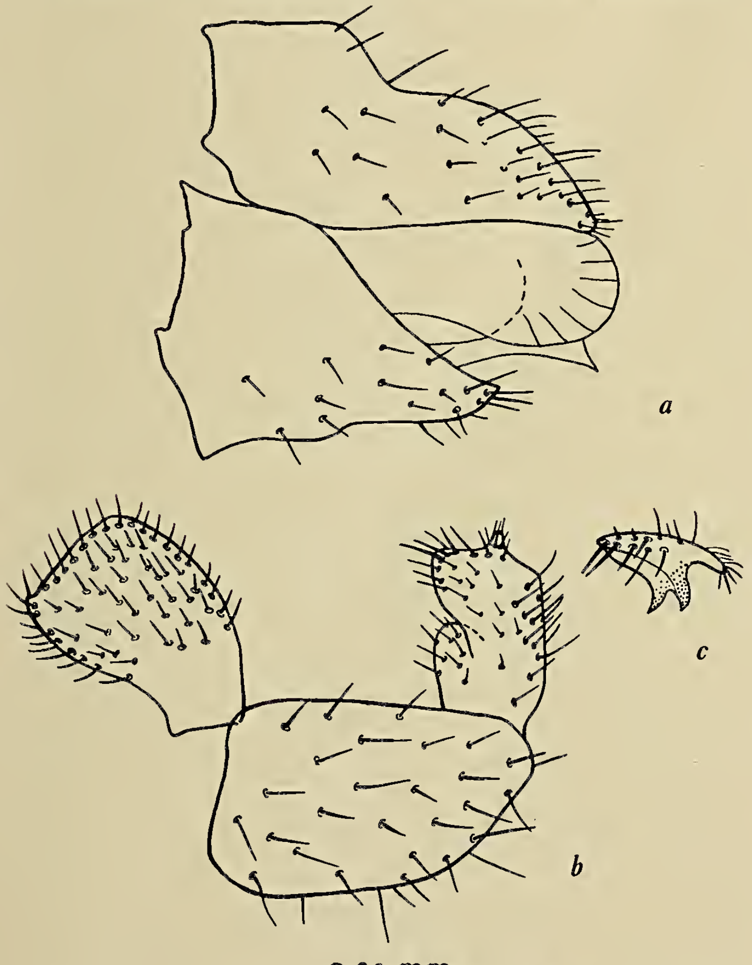

FIG. 10. *Trioza discariae* n. sp. *a*, Lateral aspect of female cauda; *b*, lateral aspect of male cauda; *c*, dorsal aspect of tip of clasper.

HOLOTYPE, male, allotype, female, numerous male and female paratypes, Halley's Lake, Cobb River Valley, January 8, from *Discaria toumatou;* Crown Range and near Kingston, January 22, many adults and nymphs from *Discaria toumatou;* adults from *Discaria toumatou*, Skipper's Bridge, December 7, 1950, E. S. Gourlay.

HOST PLANT: *Discaria toumatou* Raoul.

This is a very common and abundant species on its host and almost certainly is the form which Maskell lumped with *vitreoradiata*. His drawing of the male forceps which Ferris and Klyver explained away as being an illusion is actually only an exaggeration of the structure of the inner face of the forceps of this species seen from the proper angle.

Trioza emarginata (Ferris and Klyver)

1932 *Powellia emarginata* Ferris and Klyver, New Zeal. Inst., Trans. 63: 39, 42, pls. 8, 9.

Length to tip of folded wings 3.5 mm. (male).

Only one specimen of this distinct species was taken. This one individual was taken from a mixture of shrubs (*Pittosporum*, *Nothopanax*, *Hebe salicifolia*, etc.) forming the edge of a tongue of *Nothofagus* bush at the start of the path to Tawhai Falls, Tongariro National Park, November 26, 1950. It was taken while I was collecting specimens of *Trioza hebicola* on the *Hebe*. It is quite close to *T. vitreoradiata* as indicated by Ferris and Klyver. This, the sixth specimen known to have been captured, extends its range from Arthur's Pass to Ruapehu. It is undoubtedly abundant on its host which is as yet unknown.

Trioza falcata (Ferris and Klyver)

Fig. 11

1932 *Powellia falcata* Ferris and Klyver, New Zeal. Inst., Trans. 63: 39, 42, pls. 8, 9.

Length to tip of folded wings 4.0–4.5 mm.

COLOR: General color green to reddish brown unicolorous or commonly yellow-brown with green abdomen. Wings hyaline except light brown band along posterior margin.

STRUCTURE: Body surface finely rugose, with very short, sparse pubescence, longer on head and legs, white powdery wax deposit prominent along sides. Head slightly narrower than mesoscutum. Vertex deeply impressed discally, not overhanging anteriorly. Genal processes nearly parallel with plane of vertex, large, conical, blunt, 0.66 as long as vertex. Antennae twice as long as width of head. Pronotum short, depressed. Wings large. Forewings rounded apically, 2.5 times as long as wide, membrane with minute points behind cubitus and in some specimens a few in marginal area around to Rs (females seem to show these more than males); Rs long, sinuate, cubital cell somewhat larger than medial. Hind wings thickly set with prominent points. Metatibiae with serrate basal carina, 1 outer and 3 inner apical spines.

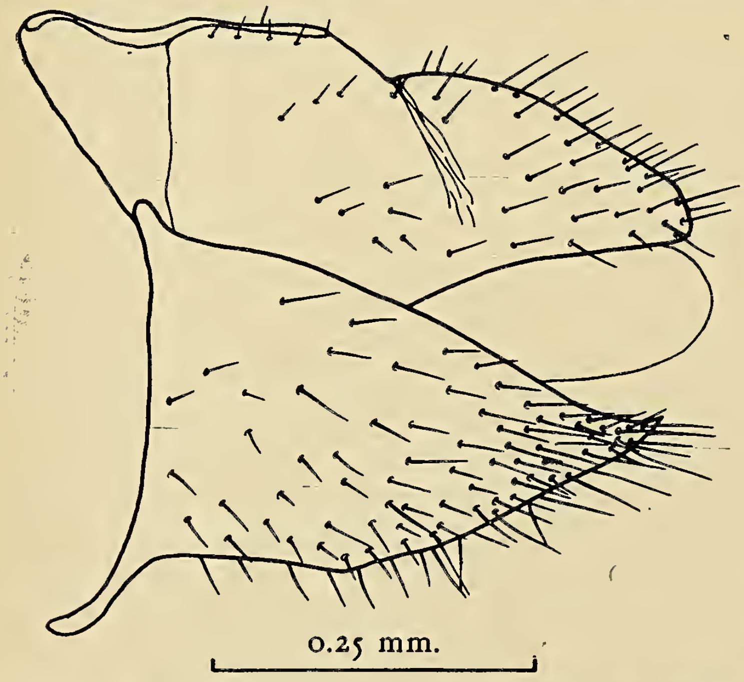

FIG. 11. Lateral aspect of female cauda of *Trioza falcata* (Ferris and Klyver).

Male genitalia as described and figured by Ferris and Klyver. Female genitalia as in *T. equalis* (Ferris and Klyver) except with sharp sulcus across dorsal valve between anus and apex, ventral valve with distinct hump.

Specimens of the species were taken abundantly at Peel Forest, South Canterbury, January 20; Mead's Landing, Lake Hawea, January 22; Whiskey Gulley, Tapanui, January 25; Tuatapere, January 28; Oban, January 31; near Tokanui, February 3.

Earlier in the season I was unable to obtain a single specimen in the type locality or elsewhere on North Island. This is perhaps because of a seasonal appearance. Without exception, those captured were taken on plants in shade or partial shade.

HOST PLANT: *Aristotelia serrata* (Forst.) Oliv.

As recorded by Ferris and Klyver, this species forms pit galls on the leaves of its host.

Trioza equalis (Ferris and Klyver)

1932 *Powellia equalis* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 47, pl. 11.

The female specimen described by Ferris and Klyver under this name is very close to *falcata* and is probably that species. Two points in their description differ from the numerous females of *falcata* at hand, however; therefore, the name is maintained and perhaps future collecting and the eventual location of Myers' collection will serve to clarify the status of *equalis*.

In *equalis* the membrane in the apical half of the forewing is set with points [punctate]. In some of the females of *falcata* there are points in the marginal area as far as the radial sector, especially in the region of the alar radulae. A more important difference lies in the genitalia. The dorsal valve of *equalis* is figured by Ferris and Klyver as nearly straight to a bluntly pointed apex, whereas that of *falcata* has a prominent transverse sulcus caudad of the anus and is much more blunt apically. The ventral valve of *falcata* has a very prominent hump which is lacking in *equalis*.

The unique type was collected at Arthur's Pass.

HOST PLANT: Unknown.

Trioza hebicola n. sp.

Fig. 12

Length to tip of folded wings 4.0–4.5 mm.

COLOR: Pale green, yellowish ventrally. Wings hyaline.

STRUCTURE: Body surface finely punctate, with sparse fine pubescence. Head narrower than mesoscutum. Vertex with strong discal impressions, bulging anteriorly. Genal processes divergent, conical, over 0.66 as long as vertex, as long as medial suture. Antennae slightly over twice as long as width of head. Thorax strongly arched. Pronotum vertical. Forewings large, very broadly rounded, less than 2.5 times as long as wide; Rs long, sinuate, cubital cell larger than medial. Metatibiae with serrate basal carina, 1 outer and 3 inner apical spines (several of the specimens at hand show 4 inner spines on one tibia).

Male proctiger strongly produced caudad, with prominent apical epiphysis. Forceps shorter than proctiger; in lateral view strongly bilobed, caudal lobe broadly rounded, anterior lobe more slender and with sharp, black, incurved tip, with basal anterior lobe from mesal face one half as long as main anterior lobe; in caudal view very broad, rounded apically, long sclerotized ridge on mesal surface near apex. Female genital segment small, shorter than rest of abdomen, dorsal valve sinuate, blunt, with prominent, raised beak apically; ventral valve nearly as long as dorsal, scoop-shaped.

HOLOTYPE, male, swept from *Hebe salicifolia* near Tawhai Falls, Tongariro National Park, December 3; allotype, female, reared from pit gall on *Hebe salicifolia*, same locality, November 26; several male and female paratypes, mostly reared from material taken November 23–26 and December 5–10.

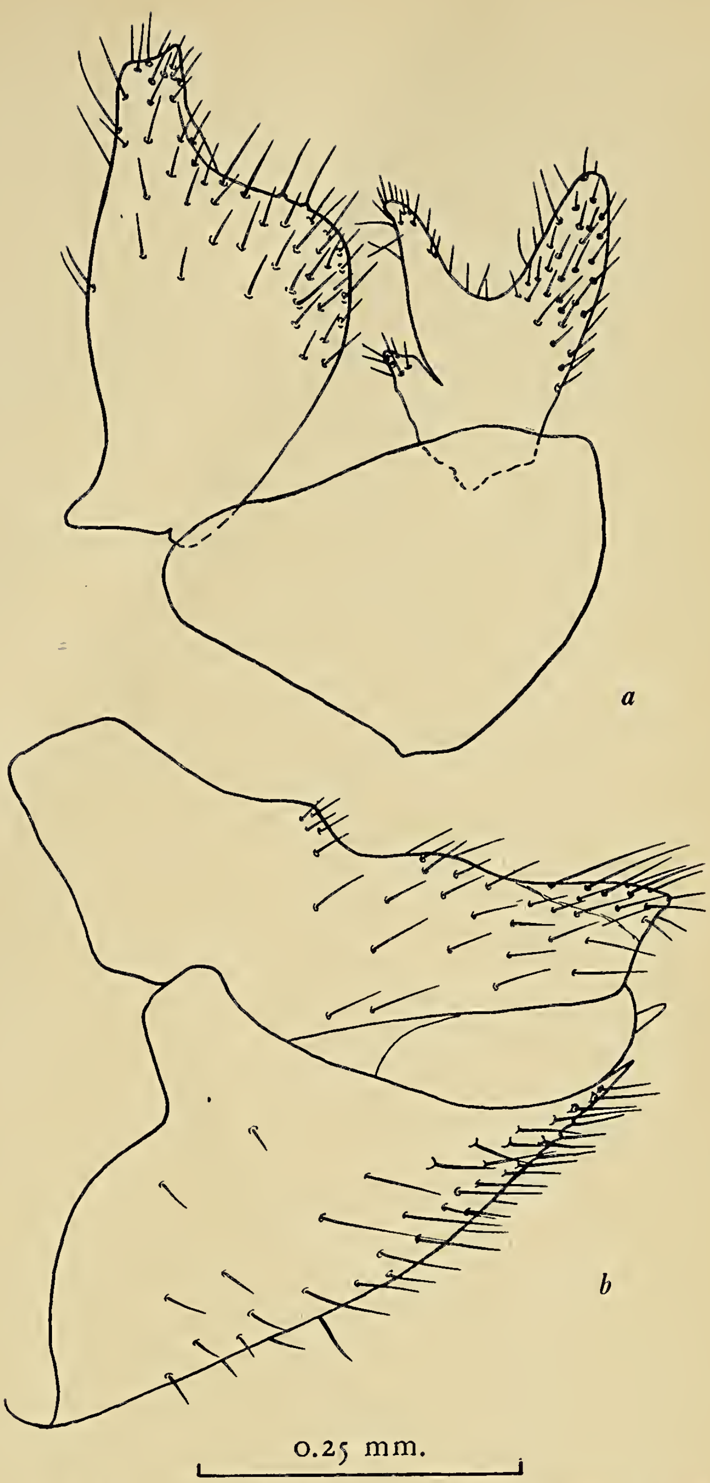

FIG. 12. *Trioza hebicola* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

HOST PLANT: *Hebe salicifolia* Forst.

Although I searched for psyllids on *Hebe salicifolia* throughout New Zealand, this is the only spot in which I obtained any specimens from it. This is a most remarkable localization. The galls produced by the nymphs are very prominent. They are thimble-shaped, up to 0.25-inch long, and project downward on the leaf. The nymphs are nearly round, surrounded by long wax tubes, and usually concave dorsally, as they accommodate themselves to the shape of the pit.

This species is a variation from the *vitreoradiata* type, the male genitalia in particular being merely a more extreme form of the same structure pattern.

Trioza bifida (Ferris and Klyver)

1932 *Powellia bifida* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 39, 43, pls. 8, 9, 10.

Supplementary notes on the species are given.

Length to tip of folded wings 2.75–3.75 mm.

COLOR: Color variable from general light green with light brown markings to yellowish brown with dark brown markings. Abdomen usually dark. Forewings fumate.

STRUCTURE: Body quite robust, surface shining, prominently punctate or imbricate. Head narrower than thorax. Vertex with strong discal impressions, bulging anteriorly. Genal processes slender, divergent, 0.66 as long as vertex. Antennae 1.6 times as long as width of head.

This very distinct species was taken in large numbers from *Olearia avicenniaefolia* at the following localities: Takaka Hill, near Nelson, January 8 and 13; Whangamoa Saddle, January 16; near Kingston, January 22; near Oban, January 29, 30, 31; Arthur's Pass, February 5; Fox Glacier, February 7. A series of 12 males and females was taken from *Metrosideros umbellata* Car. near the top of Arthur's Pass on the Otira side. One hour was spent in obtaining this short series as I thought it possible that it was a distinct species inhabiting the rata. As there was *O. avicenniaefolia* in the area, no significance can be attached to this collection. As this is a very active species, such chance occurrence on plants other than the host is to be expected. Occasional specimens were taken on several other plants, especially other species of *Olearia* where they were growing intermingled with *avicenniaefolia*.

On March 7, on the seashore near The Glen, Nelson, adults, eggs, and nymphs were taken in great numbers on *Shawia* [*Olearia*] *paniculata*. In this collection and those made at Arthur's Pass and Fox Glacier there are two distinct sizes, the smaller females being as small as the smallest males. The smaller form (2.75–3.0 mm.) is much darker in color, but no other difference is discernible.

HOST PLANTS: *Olearia avicenniaefolia* Hook. and *Shawia* [*Olearia*] *paniculata* Cheesem..

Trioza gourlayi n. sp.

Fig. 13

Length to tip of folded wings 3.0–3.25 mm.

COLOR: General color reddish brown to dark brown, vertex lighter. Genal processes green, black tipped. Forewings yellowish, transparent.

STRUCTURE: Body surface finely punctate, more or less completely dusted with powdery wax, with short, sparse pubescence. Head wider than mesoscutum. Vertex with very strong discal impressions. Genal processes slender, conical, divergent, 0.66 as long as vertex. Antennae 1.33 times as long as width of head. Eyes large, hemispherical. Pronotum very short, strongly depressed. Forewings rounded apically, membrane with prominent points except along veins; Rs long, sinuate, marginal cells nearly equal. Metatibiae with prominent basal serrations, 1 outer and 3 inner apical spines.

Male genitalia large. Proctiger long, straight, narrowed apically to small epiphysis. Forceps long (shorter than proctiger); in lateral view slightly curved cephalad, deeply notched at apex, anterior lobe blunt, posterior acute, black; in caudal view touching basally, stout then narrow, nearly straight to black tips. Female genital segment longer than rest of abdomen, large basally, strongly narrowed and attenuate in apical half, dorsal valve longer than ventral, spinose, tip blunt, ventral valve with numerous very small setae toward apex, tip sharp.

HOLOTYPE, female, allotype, male, 4 female and 2 male paratypes, Skipper's Bridge, De-

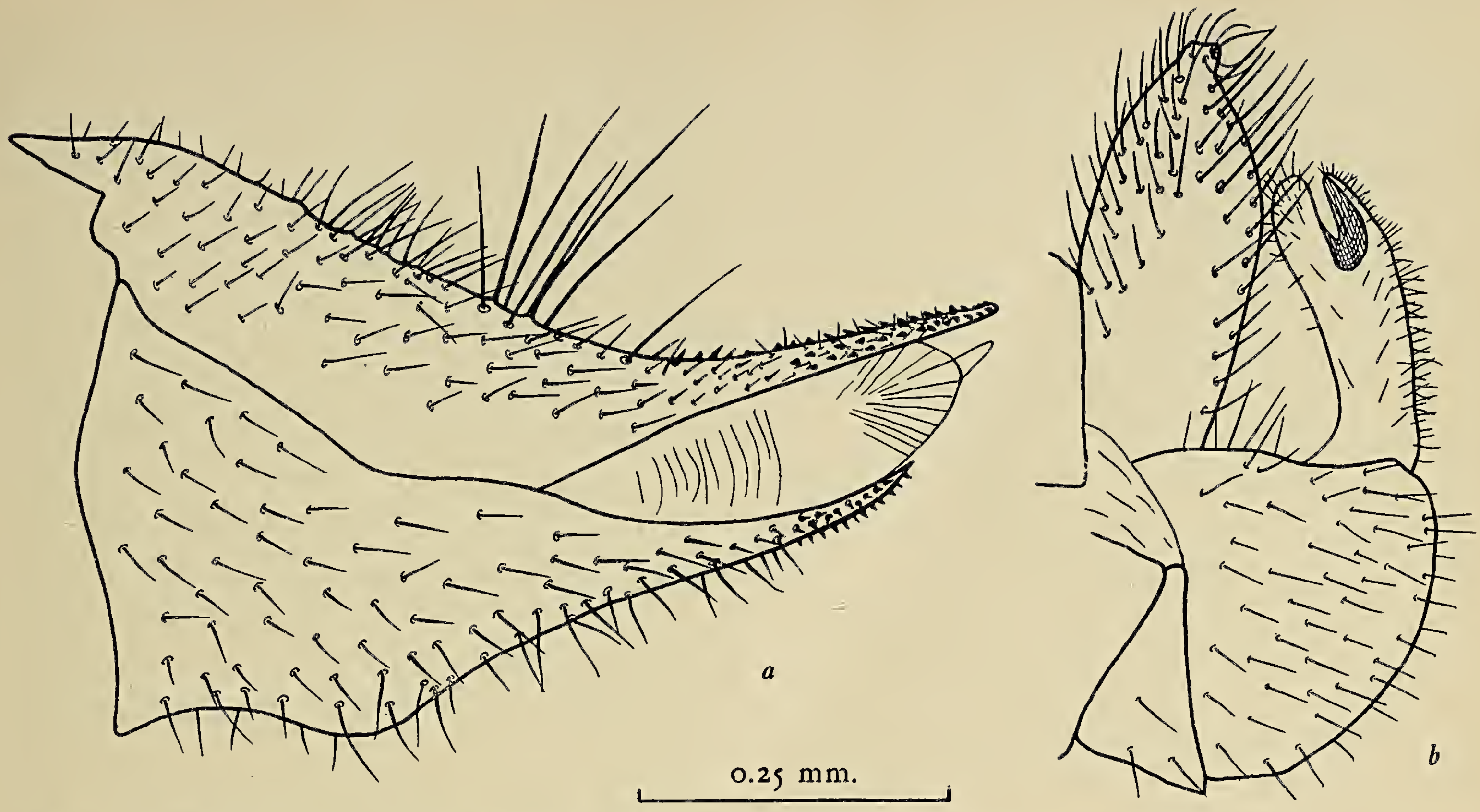

FIG. 13. *Trioza gourlayi* n. sp. *a*, Lateral aspect of female cauda; *b*, lateral aspect of male cauda.

cember 7, 1950, E. S. Gourlay, beaten from *Discaria toumatou* in company with *T. discariae*. Although I collected in the same area 6 weeks later, I was unable to find any of this species.

HOST PLANT: *Discaria toumatou* Raoul (probable).

This species is quite close to *T. bifida*. The genitalia of the female are quite different, however, and the male forceps, although similar, are more slender, curved, and the apical notch is more oblique.

It is with much pleasure that I name this species for the collector E. S. Gourlay.

Trioza panacis Maskell
Fig. 14

1890 *Trioza panacis* Maskell, New Zeal. Inst., Trans. 22: 167, pl. 12, figs. 1–12.
1932 *Powellia panacis* Ferris and Klyver, New Zeal. Inst., Trans. 63: 48.

Length to tip of folded wings 3.75–4.5 mm.

COLOR: Uniformly green to yellow. Forewings slightly embrowned except along veins.

STRUCTURE: Body surface minutely rugose, with very short scattered pubescence. Head as wide as mesoscutum. Vertex short, with round discal impressions, bulging anteriorly. Genal processes short, conical, divergent, 0.66 as long as vertex. Antennae very slightly less than twice as long as width of head. Pronotum not depressed below plane of vertex. Forewings large, narrowly rounded apically, 2.7 times as long as wide, membrane with points on area behind cubitus; Rs slightly sinuate, cubital cell distinctly larger than medial, Cu_1 very strongly arched. Hind wings long, with prominent points throughout. Metatibiae with serrate basal carina, 1 outer and 3 inner apical spines.

Male proctiger large with prominent apical epiphysis, caudal wings wide, flattened. Forceps shorter than proctiger; in lateral view broad, nearly straight sided, prominent basal bulge anteriorly, caudal margin obliquely excavate in apical third, anterior margin round at tip to blunt, black, apical tooth, heavy, stiff setae on anterior margin, short stiff setae on caudal and mesal surfaces; in caudal view stout, nearly straight to slightly incurved sharp black tips, basal bulge on lateral surface; in dorsal view tips black, blunt, truncate to slightly excavate. Female genital segment small, valves almost equal in length; dorsal margin of dorsal valve strongly sinuate, apex

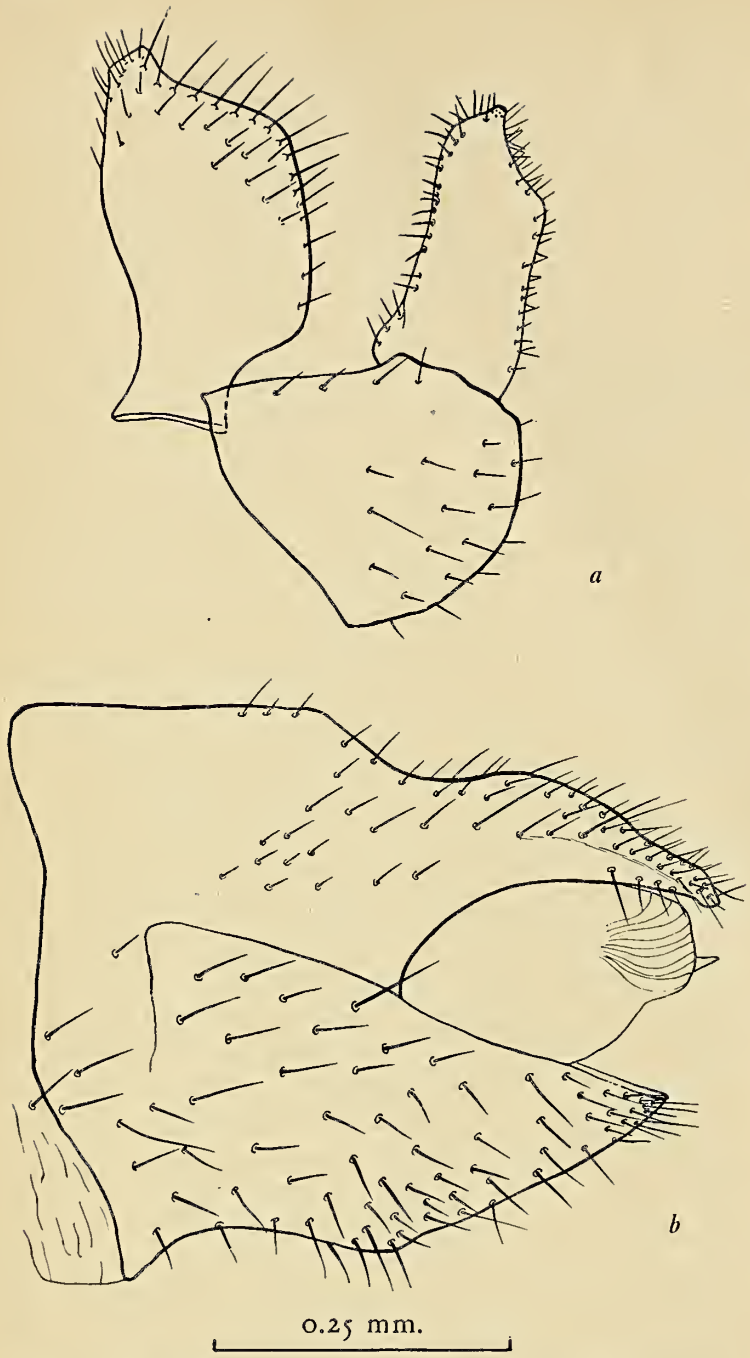

FIG. 14. *Trioza panacis* Maskell. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

downcurved, blunt; ventral valve strongly sinuate also, apex sharp.

Nymph (last stadium) 2.4 mm. long, 1.8 mm. wide across wing pads. The nymph is very distinctive, being large, thick, very strongly convex dorsally, and highly pigmented as described by Maskell. The prominent rounded protuberances on the thoracic dorsum are the most easily seen of the peculiar structures present. There is also a less prominent pair on the head. The derm of the dorsum is grossly punctate throughout. The venter is minutely spinulose. Small setae scattered over dorsal surface including thoracic and cephalic protuberances. The abdominal segments are distinctly marked. The wing pads extend cephalad well beyond the eyes, nearly equaling the tip of the head. Marginal sectasetae goblet-shaped, those on caudal margin somewhat more elongate. Anal pore ring with ends as wide as center, transverse, flattened, broadly rounded at ends, consisting of a single row of pores enclosing a row of small teeth.

SPECIMENS EXAMINED: Neoholotype, female, and allotype, male, Manapouri, January 24, 1951. The female was reared from a nymph on *Pseudopanax* sp. Many other specimens were taken at various localities, all on *Pseudopanax*. Very few were found on the juvenile trees but they were abundant on mature specimens of the host at the time it was in bloom.

HOST PLANT: *Pseudopanax* spp.

Maskell in describing *T. panacis* did not distinguish between this species and the very closely related form found on *Nothopanax* spp. Ferris and Klyver had three female specimens of the latter which they described under the name *Powellia irregularis*. Fortunately Maskell included a rather good description of the nymph which is, in this species, much more distinctive than the adult. The highly convex body form, strong pigmentation, and especially the prominent protuberances on the thorax make it unmistakable. On the basis of his having actually described and figured this nymph rather than the other (the description of the adult serving for either equally well) the epithet is established for the species which inhabits *Pseudopanax*. As confirming evidence, there is in the Maskell material at the Cawthron Institute a small pill box labeled "Trioza panacis (psyllid of Lancewood)," which contains numerous nymphs of this species.

Ferris and Klyver mention the presence of points ("punctations") present on the membrane of the forewing of *irregularis*. This character (which seems to hold in this instance) plus their excellent drawing of the female genitalia leave no doubt as to the identity of *irregularis*.

As Maskell mentions, the nymphs very commonly retain the cast exuvia attached to the rear end of the body; not only the preceding one as he states but frequently a last stage nymph ("pupa" of Maskell) will have a long "tail" consisting of all its exuvia. L. J. Dumbleton first called this to my attention when giving me some nymphs which he had taken on the host plant in the Rai Valley. I have not encountered this phenomenon in psyllids heretofore but at least one of the other New Zealand species (*T. subvexa*) has the same habit, as I have found one or two nymphs in this condition.

Trioza irregularis (Ferris and Klyver)

Fig. 15

1932 *Powellia irregularis* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 47, pl. 11.

The adult of this species is very similar to *T. panacis.* It is smaller than the latter (3.25–3.75 mm. long) and less robust in form. The vertex is proportionately narrower. The antennae are shorter in proportion to the width of the head, being about 1.5 times as long as the width of the head, whereas in *panacis* they are nearly twice as long. The forewings are more slender and somewhat more pointed at the apex, the cubital cell is smaller, Cu_1 is less highly arched, the membrane is completely hyaline or very nearly so and has quite prominent points throughout except along the veins. (This is one of the most usable characters although, as pointed out previously, it is very variable in *vitreoradiata*, and its validity is therefore questionable.) In many individuals the thoracic dorsum is dark brown.

The genitalia show differences from *panacis*, largely of degree. The dorsal valve of the female is distinctly less sinuate and is straight apically. The male shows only slight differences as figured.

The nymphs of the two species are by far more distinctive than the adults. The last-stage nymph of *irregularis* is smaller (2 mm. long, 1.25 mm. wide across the wing pads), is almost flat dorsally, lacks the dorsal protuberances, is finely punctate dorsally, is without dorsal setae, has numerous slender setae over the venter in addition to the minute spinules present, the wing pads do not extend forward beyond the eyes, and the anal ring is of a different shape, being more slender and angular.

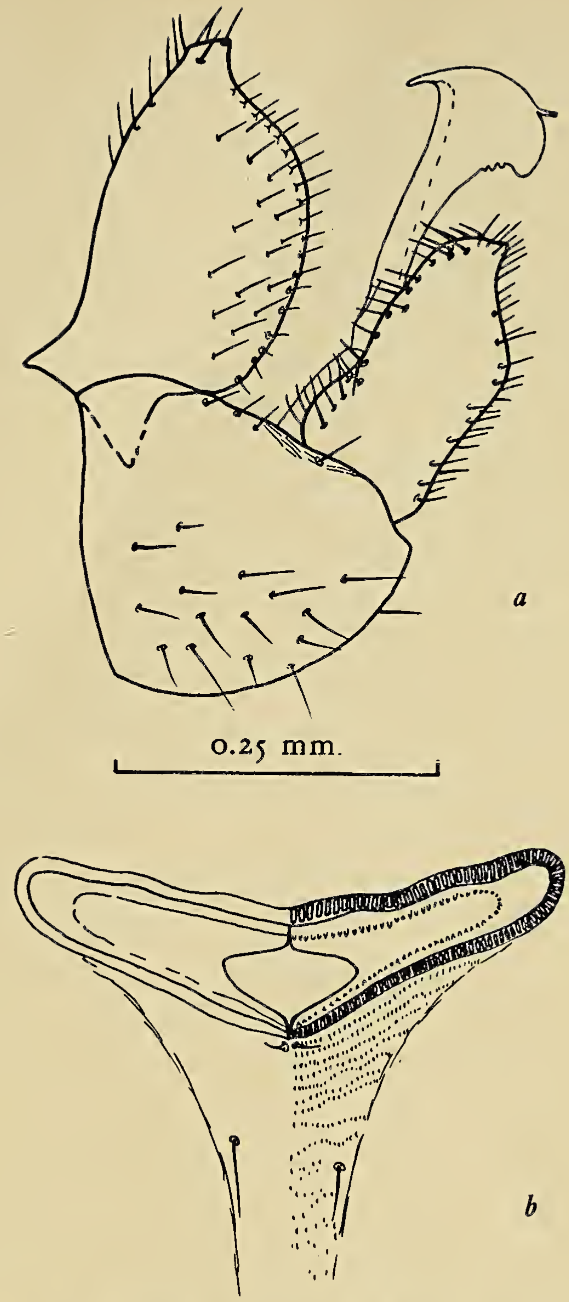

FIG. 15. *Trioza irregularis* (Ferris and Klyver). *a*, Lateral aspect of male cauda; *b*, anal pore ring of nymph.

Many specimens were taken throughout New Zealand from North Auckland to Stewart Island, at all possible altitudes and throughout the season, from various species of *Nothopanax*, including *N. arboreum*, *N. simplex*, *N. edgerleyi*, *N. colensoi*, *N. anomolum.* The nymphs cause the formation of pits on the leaves, within which they lie, surrounded by a prominent white fringe of wax tubes.

HOST PLANTS: *Nothopanax* spp.

Trioza schefflericola n. sp.

Fig. 16

On December 5, 1950, I collected a series of adults, nymphs, and eggs, from *Schefflera digitata* in the Mamaku Hills. This was the only certain occurrence of a psyllid on this host which I discovered although I believe that an earlier collection near Mangamuka was from both *Nothopanax* and *Schefflera*. Both the nymphs and adults looked quite distinct in the field. The nymphs, bright orange in color, were very flat, on the upper surface of the leaves, without any conspicuous fringe of wax tubes. They had not produced any visible structural malformation of the host tissue but each was surrounded by a discolored necrotic area. Careful examination in the laboratory, however, shows them to be very similar to *T. irregularis*. The adults have proportionately much larger wings, the membrane of the forewings is without points except behind cubitus, and the forewing is yellow. The shape of the anal ring of the nymph is different, being more strictly transverse and not narrowed toward the ends. All the other differences I have found are simply slight differences of degree.

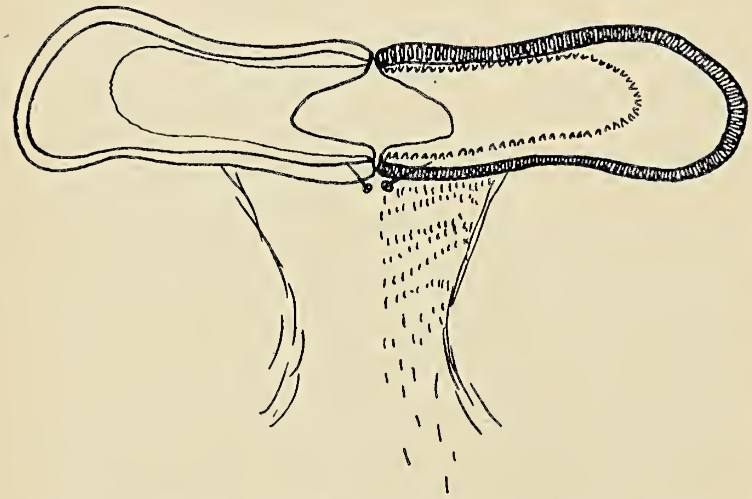

FIG. 16. *Trioza schefflericola* n. sp. Anal pore ring of nymph.

It is with considerable doubt that I designate this as a distinct species. Only further work and some biological information can definitely determine its status. I believe that such information will indicate that it is distinct. If it does not, the sinking of this epithet into synonymy will cause no confusion.

HOLOTYPE, female, allotype, male, several male, female, and nymphal paratypes, Mamaku Hills, December 5. Nymphs taken from the same host plant are in the Plant Diseases Division Collection: Titirangi, August 5, 1945, M. W. Carter.

HOST PLANT: *Schefflera digitata* Forst.

Trioza alseuosmiae n. sp.

Fig. 17

Length to tip of folded wings 3.25–3.5 mm.

COLOR: Body straw, abdomen greenish in some specimens. Forewings yellow.

STRUCTURE: Body small, surface finely rugose. Head large, as wide as mesoscutum. Vertex with strong discal impressions, bulging anteriorly. Lateral ocelli large, well forward on vertex. Genal processes small, stout, somewhat divergent apically, 0.5 as long as vertex (almost as long as medial suture). Antennae twice as long as width of head. Eyes large, bulging, hemispherical. Postocular and occipital areas strongly developed. Thorax strongly arched. Pronotum large, nearly vertical, not depressed below plane of vertex. Forewings very large in proportion to body, angular apically, 3 times as long as wide, membrane without points, surface very finely roughened; Rs moderately long, sinuate, marginal cells large, cubital slightly larger than medial. Metatibiae with prominent serrate basal carina, 1 outer and 3 inner apical spines.

Male proctiger long. Forceps much shorter than proctiger; in lateral view broad, anterior and caudal margins slightly sinuate, apex truncate with blunt black tooth at caudal margin; in caudal view stout, evenly arched to blunt black tips. Elbow of aedeagus highly sclerotized, brown or black. Female genital segment shorter than rest of abdomen; dorsal valve straight to narrowly blunt apex; ventral

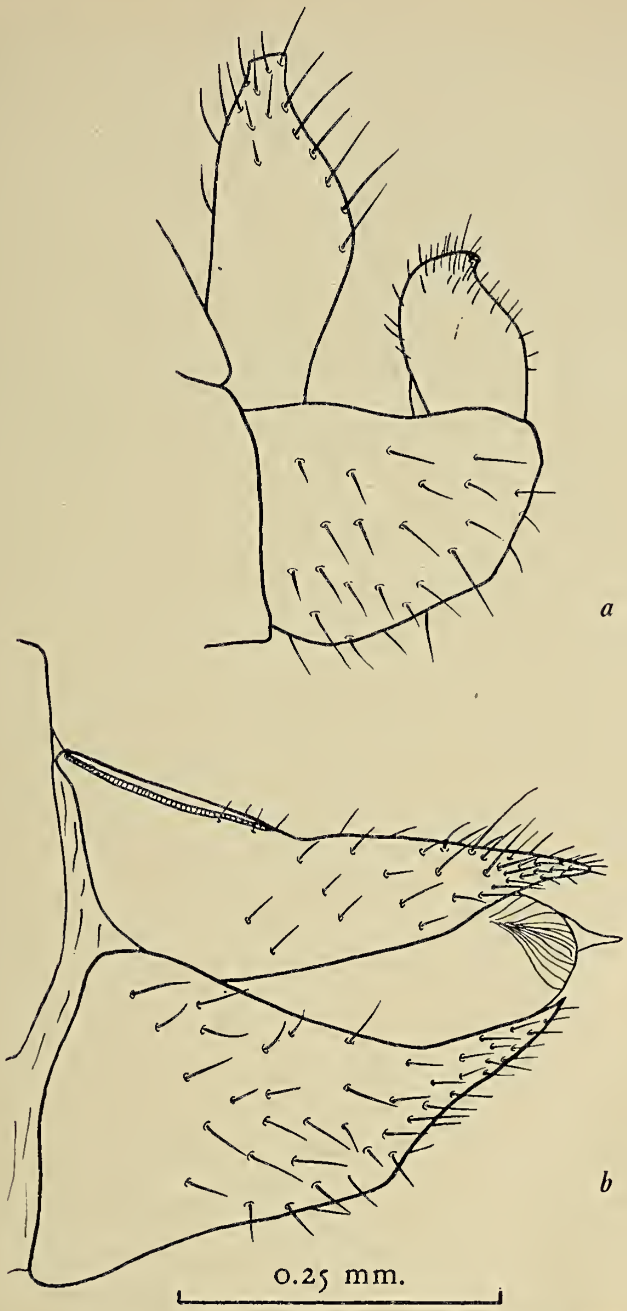

FIG. 17. *Trioza alseuosmiae* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

valve long, almost equaling dorsal, apical two fifths sharply upturned, scoop-shaped.

HOLOTYPE, male, allotype, female, several male and female paratypes, Mamaku Hills, near Rotorua, December 5. One male, Mamaku Gorge, December 6. Last-stadium nymphs, Mamaku Hills, September 26. All specimens taken from *Alseuosmia*.

HOST PLANT: *Alseuosmia macrophylla* A. Cunn.

The nymphs, which were taken from the host in early spring, when it was just beginning to bloom, were in pits on the leaves. At that time no adults were present. Upon returning to the same plants in December, adults were found. No specimens could be captured a short distance away in a portion of the same bush which had been cut over so that the sun had been let in, although the *Alseuosmia* was very abundant and in a thriving condition. All the specimens taken were in dense bush where the sunlight does not penetrate. It would seem that the ecological requirements of this species limit it to the host plant growing as underbrush in dense bush.

Trioza acuta (Ferris and Klyver)

1932 *Powellia acuta* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 39, 43, pl. 10.

The only collection made of this species was October 29, at which time it was taken in large numbers from its host plant, *Cassinia leptophylla* R. Br., on a ridge above Croisilles (or Croixelles). A large percentage of those taken were copulating at that time.

This is a small but robust species. It ranges in length from 2.0 to 2.25 mm.

Trioza parvipennis n. sp.

Fig. 18

Length to tip of folded wings 2.75–3.75 mm.

COLOR: General color cinereous to straw color, abdomen darker dorsally. Wings somewhat fumate. Some specimens mostly green.

STRUCTURE: Body robust, finely pubescent, surface rugulose. Head large, wider than mesoscutum, scarcely deflexed. Vertex broad with strong discal impressions, bulging anteriorly. Genal processes large, conical, blunt, 0.75 as long as vertex. Antennae slightly longer than width of head. Eyes large. Thorax quite flat for genus. Pronotum wide, not depressed below plane of vertex. Forewings small, narrowed in apical third, rounded apically, 2.5 times as long as wide, membrane rugose, semitransparent, thickly set with points except along veins, points especially large near margin of wing between Rs and M_1, in some specimens similar to the alar radulae, veins setate; Rs long, somewhat sinuate, marginal cells very small, approximately equal. Hind wings 0.75 as long as forewings, with points throughout. Metatibiae with serrate basal carina, 2 principal teeth, 1 outer and 3 inner apical spines.

Male proctiger long, surface minutely imbricate, caudal margin produced. Forceps large, 0.6 as long as proctiger; in lateral view gradually broadened from near base to obliquely truncate apex; in caudal view broad, slightly curved to truncate apex, medial edge blunt, black; in dorsal view medial edge black with two teeth, one broad, blunt, caudal and one sharp, medial. Aedeagus as figured. Female genital segment large, as long as rest of abdomen, entire segment more or less bent dorsally. Both valves swollen basally then acuminate, styliform to sharp apices, dorsal longer than ventral, latter strongly papillate, former less so. Ovipositor exceeding valves, lateral palps slender, heavily sclerotized, rugose, exceeding dorsal valve, acute apically.

HOLOTYPE, male, allotype, female, 2 male and 6 female paratypes taken from *Senecio adamsii* near Lake Peel, approximately 4,000 feet, January 13.

HOST PLANT: *Senecio adamsii* Cheeseman.

This species resembles *T. acuta* Ferris and Klyver in its robust form, small wings, and general form of genitalia. It was taken in small numbers from isolated specimens of its host plant scattered on the steep mountainside about a mile below Lake Peel. The host plant was at first thought to be a species of *Olearia* but Lush has determined it as *Senecio adamsii*.

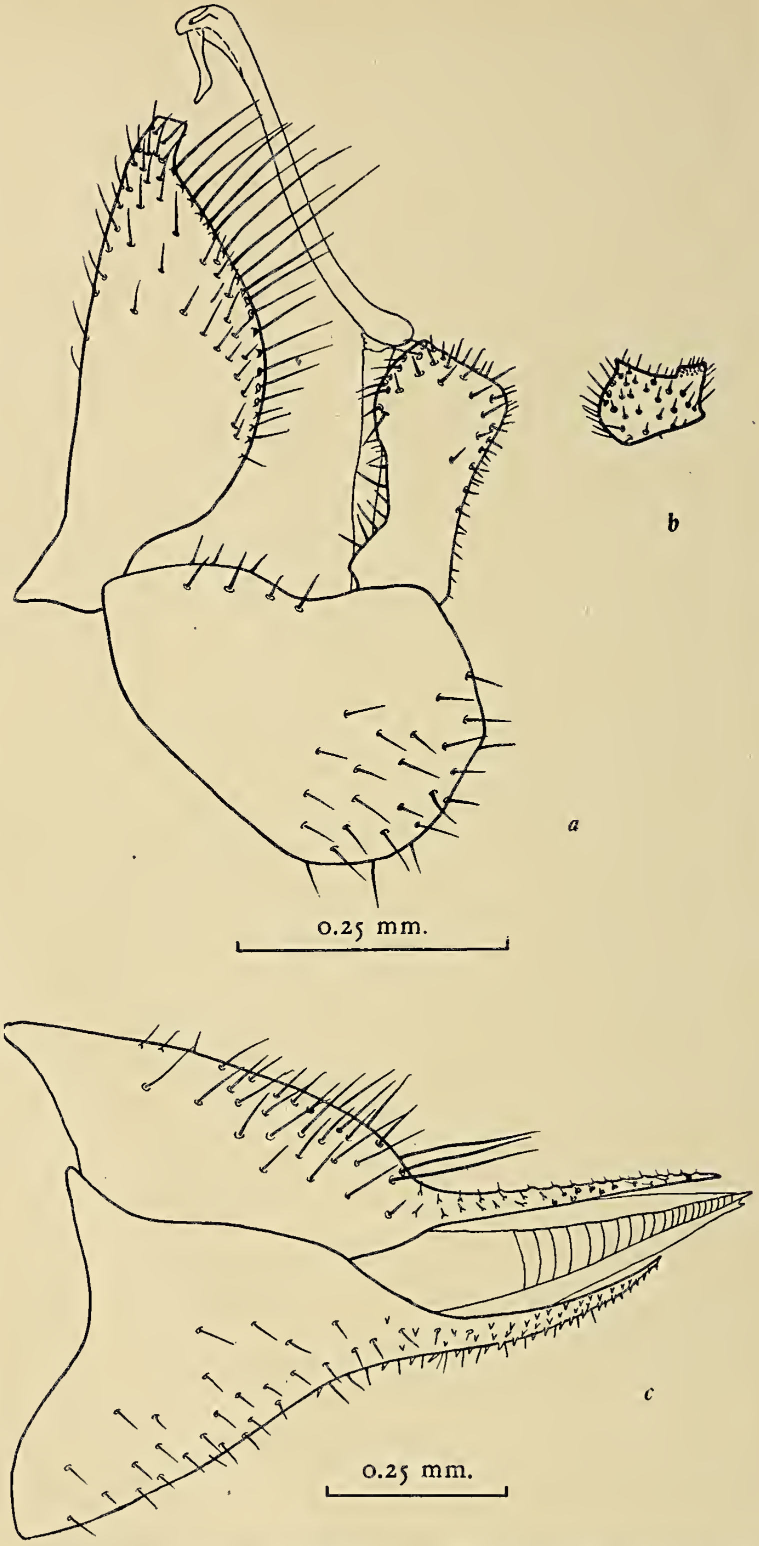

FIG. 18. *Trioza parvipennis* n. sp. *a*, Lateral aspect of male cauda; *b*, dorsal aspect of tip of clasper; *c*, lateral aspect of female cauda.

Trioza subacuta (Ferris and Klyver)

1932 *Powellia subacuta* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 39, 44, pl. 10.

Some supplementary notes to the original description are:

Length to tip of folded wings 3.25–3.75 mm.

COLOR: General color white to yellow. Abdomen, especially in male, often chocolate brown. Wings hyaline. Body more or less covered with powdery wax, especially prominent on first abdominal tergite.

STRUCTURE: Body slender, surface rough, with short sparse pubescence. Head large, as wide as mesoscutum. Genal processes slender, divergent, acute, 0.8 as long as vertex. Antennae very slightly over twice as long as width of head. Postocular areas small. Pronotum short, much depressed below plane of vertex. Forewings nearly 3 times as long as wide, bluntly angular. The apex of the male forceps is heavily sclerotized, black, and much more obliquely truncate than Ferris and Klyver's figure would indicate.

HOST PLANT: *Brachyglottis repandra* Forst. This species has been taken in abundance on rangiora, *Brachyglottis repandra*, at several localities. Many nymphs, a few adult females, and several mummified males were taken near Nelson on October 19. Adults were present on rangiora in abundance at Rotorua, December 4. Other collections are: Waitakere Hills, near Auckland, September 29, 1950, W. Cottier; Cape Rainga, October 3, 1950, W. Cottier and L. D. Tuthill; near Mangamuka, October 4; Waipoua Forest, October 5; Buller's Bush, near Levin, October 27; Palmerston North, several dates in October and November; lower reaches of Mount Ruapehu, November 18; near Taumarunui, November 26; Takaka Hill, near Nelson, January 13.

I think there is no doubt of the identification of this species. I cannot understand, however, the statement by Ferris and Klyver that it is "very close to *P. acuta*," as it differs markedly in body form, head characters, and in size and shape of the wings. It is very similar to the following several species which are found on other shrubby Compositae, i.e., *Olearia* and *Senecio*.

Trioza doryphora (Maskell)

Fig. 19

1880 *Powellia doryphora* Maskell, New Zeal. Inst., Trans. 12: 291, 301.

Length to tip of folded wings 3.5–3.75 mm.

COLOR: General color white to greenish white or pale yellow. Dorsum of abdomen brown to black. Males darker. Forewings slightly embrowned except along veins.

STRUCTURE: Surface of body rough, with short, sparse pubescence, more or less covered with powdery wax. Head narrower than mesoscutum. Vertex impressed discally, slightly bulging over base of genae. Genal processes slender, conical, divergent, 0.7 as long as vertex. Antennae slightly less than twice as long as width of head. Eyes large, hemispherical. Postocular area large. Pronotum strongly depressed, below plane of vertex. Mesonotum strongly produced anteriorly, overhanging pronotum. Forewings large, broadly rounded, 2.5 times as long as wide; membrane roughened, set with minute points except along veins; Rs very long, sinuate, cubital cell somewhat larger than medial. Hind wings large, transparent, set with prominent points. Metatibiae with somewhat

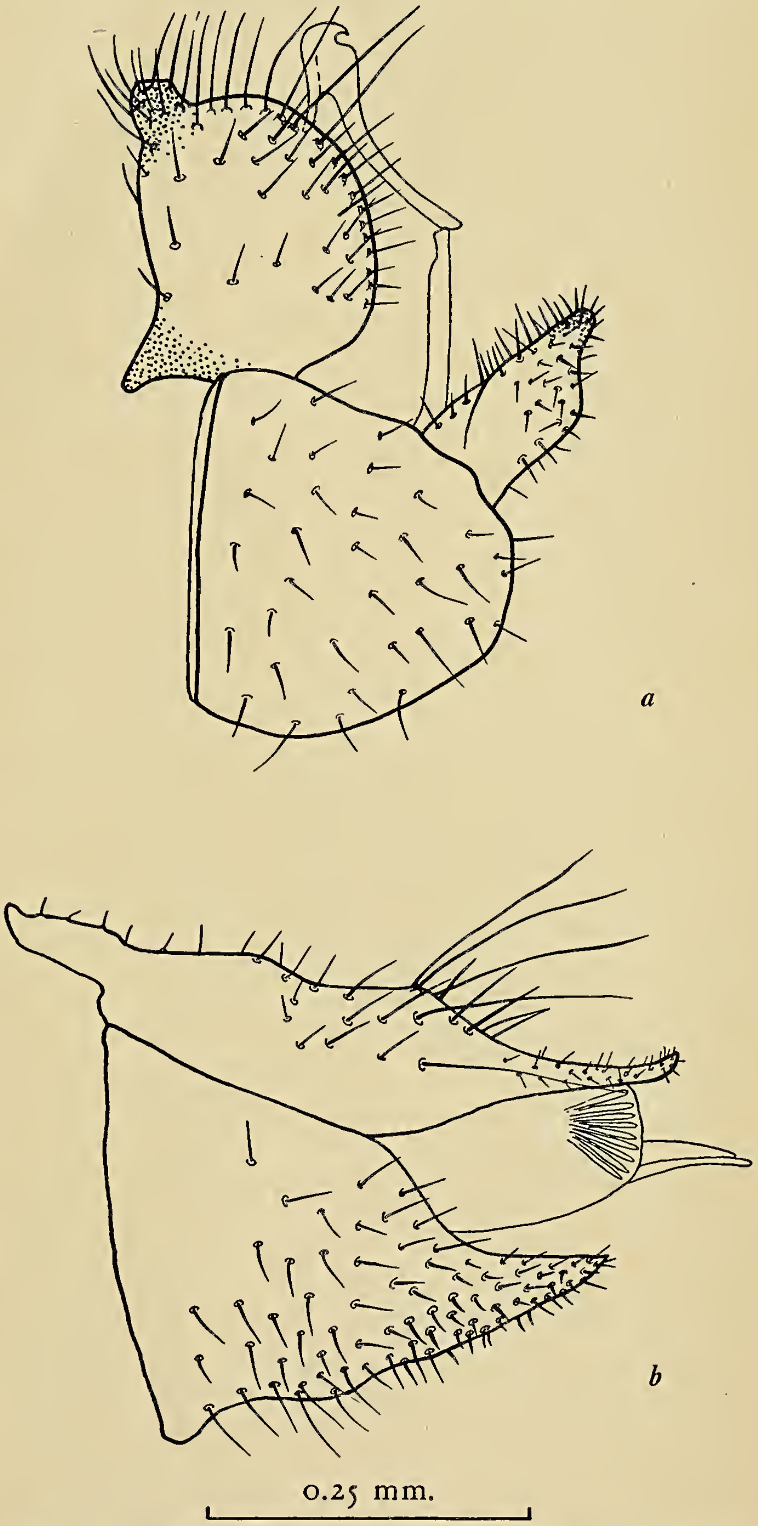

FIG. 19. *Trioza doryphora* (Maskell). *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

oblique serrate basal carina, 1 outer and 3 inner apical spines.

Male genitalia large. Proctiger strongly, roundly produced caudad with small apical epiphysis, long setae along margin, black basally and anteriorly at apex. Forceps shorter than proctiger, in lateral view broad at base, nearly parallel margined, near apex caudal margin abruptly excavate, anterior margin continued as black, blunt, incurved tooth; in caudal view touching basally, stout, arched to sharp black tips, medial surface thickly set with setae. Female genital segment shorter than rest of abdomen, dorsal valve sinuate, apical portion attenuate, dark, upturned apically to sharp tip, a tuft of long setae on dorsal surface; ventral valve shorter than dorsal, sharp apically, set with short stout setae.

HOLOTYPE, male, allotype, female, reared from pseudogalls formed by the curling edges of young leaves of *Olearia ilicifolia*, taken at Waituhi Trig in the Huahangaroa Mountains, December 8; numerous paratypes, mostly males, with same data. Additional paratypes as follows: 4 swept from host plant at Waituhi Trig, December 8; numerous males and females swept and reared from host plant, near Homer Tunnel, January 23; numerous males and females swept and reared from host plant near Tokanui, February 3. A few nymphs, taken from galls on *Olearia ilicifolia*, Mount Egmont, April 22, 1946, by M. W. Carter, also seem to be this species.

HOST PLANT: *Olearia ilicifolia* Hook.

Through the courtesy of Dr. W. Cottier, I received some twigs of *Olearia ilicifolia* with galls and nymphs taken in a nursery at New Plymouth in October and the additional information that the insect was in epidemic proportion throughout the King Country where the plant is rather widely used as a hedge plant. The area near Waituhi Trig had an almost solid stand of the host and practically every young leaf was distorted by the feeding of the nymphs.

At Waituhi Trig, syrphid larvae were feeding on the nymphs, and one adult was reared out. It was determined by Dr. David Miller to be an undescribed species, apparently belonging to the genus *Platycheirus*.

This species is similar to *T. subacuta* (Ferris and Klyver) but is distinguishable by the much broader and rounded wings, the upcurved tip of the dorsal valve of the female, and by the shape of the male forceps.

In his paper of 1880, Maskell states "I have found, on *Olearia ilicifolia*, another species [of *Powellia*], wanting the long glassy fringe of the earlier stage, and having, instead, a row of lanceolate spines. I would call this species *P. doryphora*." It is probable that the species here described is the same as that which Maskell had, although this comment on the nymph would fit either of the two species known from *Olearia ilicifolia* equally well. The nymphs do bear lanceolate setae scattered over the abdomen, not merely a row on the margin. Actually these setae are surrounded in life by a short tube of wax secreted from their basal plate. By fixing Maskell's name on this species any possible future confusion will be avoided.

As there is no indication that any of Maskell's specimens of this species were preserved, types are designated from the material at hand.

Trioza subvexa n. sp.

Fig. 20.

Length to tip of folded wings 3.25–3.75 mm.

COLOR: General color cinereous to straw color, to green. Abdominal tergites more or less brown. Forewings slightly yellowish.

STRUCTURE: Body slender, small, surface rough, sparsely pubescent, and more or less covered with powdery wax. Head as wide as mesoscutum. Vertex nearly flat between lateral ocelli, bulging anteriorly over each antennal base. Genal processes slender, divergent, 0.8 as long as vertex, with long prominent setae. Eyes large, hemispherical.

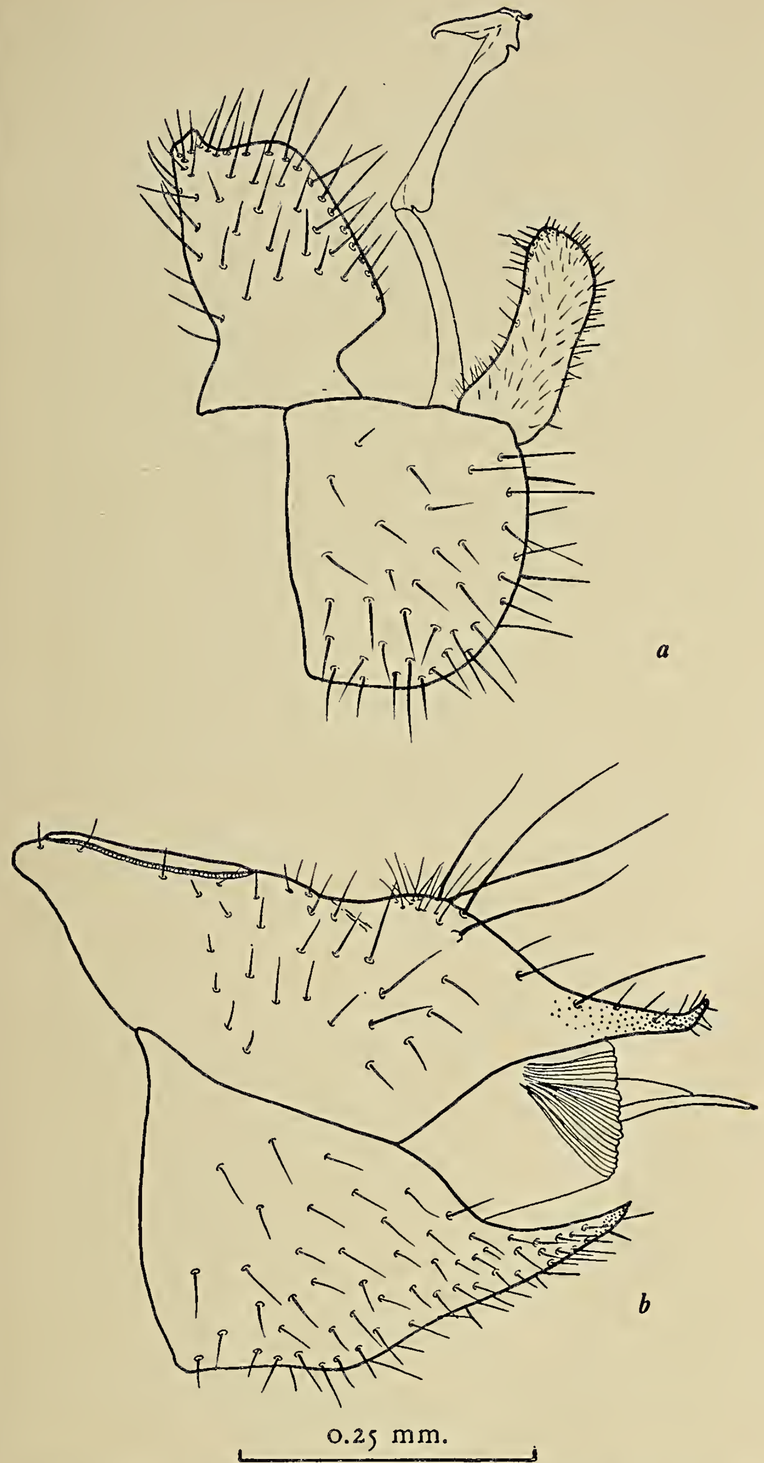

FIG. 20. *Trioza subvexa* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

Postocular area large. Antennae twice as long as width of head. Thorax strongly arched. Pronotum narrow, depressed below plane of vertex. Forewings large, narrowly rounded apically (not angular), 2.75 times as long as wide; membrane thickly set with points except along veins; Rs long and sinuate, cubital cell slightly larger than medial. Hind wings large, thickly set with points. Metatibiae with serrate basal carina, 1 outer and 2 inner apical spines.

Male genitalia of moderate size. Proctiger short, broadly produced caudad, somewhat rectangular in lateral view. Forceps shorter than proctiger, with abundant fine setae; in lateral view nearly straight, caudal margin slightly sinuate, apex rounded, black; in dorsal view tips blunt, black margined; in caudal view stout, slightly arched, tips incurved, black, sharp. Female genital segment nearly as long as rest of abdomen; dorsal valve descending, with median hump bearing tuft of very long setae, apical third attenuate, black, apex sharply upturned, sharp; ventral valve shorter than dorsal, apical portion slender to sharp tip.

HOLOTYPE, male, allotype, female, 8 male and 5 female paratypes Takaka Hill (between Nelson and Takaka), January 8 and 13; 2 female paratypes, Whangamoa Saddle, near Nelson, January 16; 1 male and 2 female paratypes, Arthur's Pass, February 5. All these specimens were swept from *Olearia avicenniaefolia.* Numerous additional paratypes, males and females, were reared from pseudogalls formed by the curled edges of young leaves of *Olearia avicenniaefolia* taken at Fox Glacier on February 7. Nymphs of all stages were present at that time. Nymphs and adults were also taken at Waiho by L. J. Dumbleton on November 20, 1950.

HOST PLANT: *Olearia avicenniaefolia* Hook.

This species is very close to *Trioza subacuta* (Ferris and Klyver) but may be distinguished from it by the less angular wings and the genitalia—the dorsal valve of the female is upturned apically instead of straight, the male forceps are rounded rather than obliquely truncate apically.

Trioza compressa n. sp.

Fig. 21

Length to tip of folded wings 3.75–4 mm.

COLOR: General color light brown with abdomen dark dorsally and either bluish green or cinereous ventrally. Forewings distinctly fumate.

STRUCTURE: Body surface rough, more or less covered with powdery wax. Head as wide as mesoscutum. Vertex strongly impressed, bulging anteriorly. Genal processes long, slender, acute, divergent, nearly as long as vertex. Antennae slightly over twice as long as width of head. Eyes large. Postocular areas prominent but smaller than in related species. Thorax well arched. Pronotum very strongly depressed below vertex. Forewings large, bluntly angular, with prominent points on membrane except along veins, 2.66 times as long as wide; Rs long, sinuate, marginal cells about equal. Metatibiae with prominent teeth basally, 1 outer and 3 inner apical spines.

Male genitalia large. Proctiger strongly swollen caudad, with small apical epiphysis. Forceps shorter than proctiger; in lateral view broad and straight basally, obliquely truncate to blunt, black apex; in caudal view broad basally, narrowed to apex; outer margin strongly arched in basal half then nearly straight to touching apex, inner margins touching basally, excavate, then produced, then evenly tapered to apex, very stout setae on broad lobe thus formed; in dorsal view tips black, truncate. Female genital segment short, about two thirds as long as rest of abdomen; dorsal valve steeply descending to short, straight, styliform apex, with small hump bearing tuft of long setae; ventral valve nearly as long as dorsal, very strongly compressed midway, apical portion brown, thickly set with short retrorse setae.

HOLOTYPE, male, allotype, female, 3 male and 3 female paratypes, Whangamoa Saddle, January 16, taken on *Olearia arborescens*. Additional paratypes: Falls Creek in upper Hollyford Valley, January 23; Oban, January 29, taken on *Olearia arborescens*, in great numbers; 1 female taken at The Neck, Stewart Island, February 1, on *O. arborescens;* Arthur's Pass, February 5, taken on *O. arborescens;* Fox Glacier, February 7, taken on an *Olearia* determined by Lush as *O. macrodonta* or *arborescens* (as *macrodonta* is considered to be a hybrid between *arborescens* and *ilicifolia*, it is interesting that from the single bush of this form which I could discover I obtained *T. compressa*, a species which is abundant on *arborescens*, and *T. crinita*, a species found otherwise only on *ilicifolia*); a series of males and females taken from *Olearia rani* growing in a gully at Te Waewae Bay, January 28.

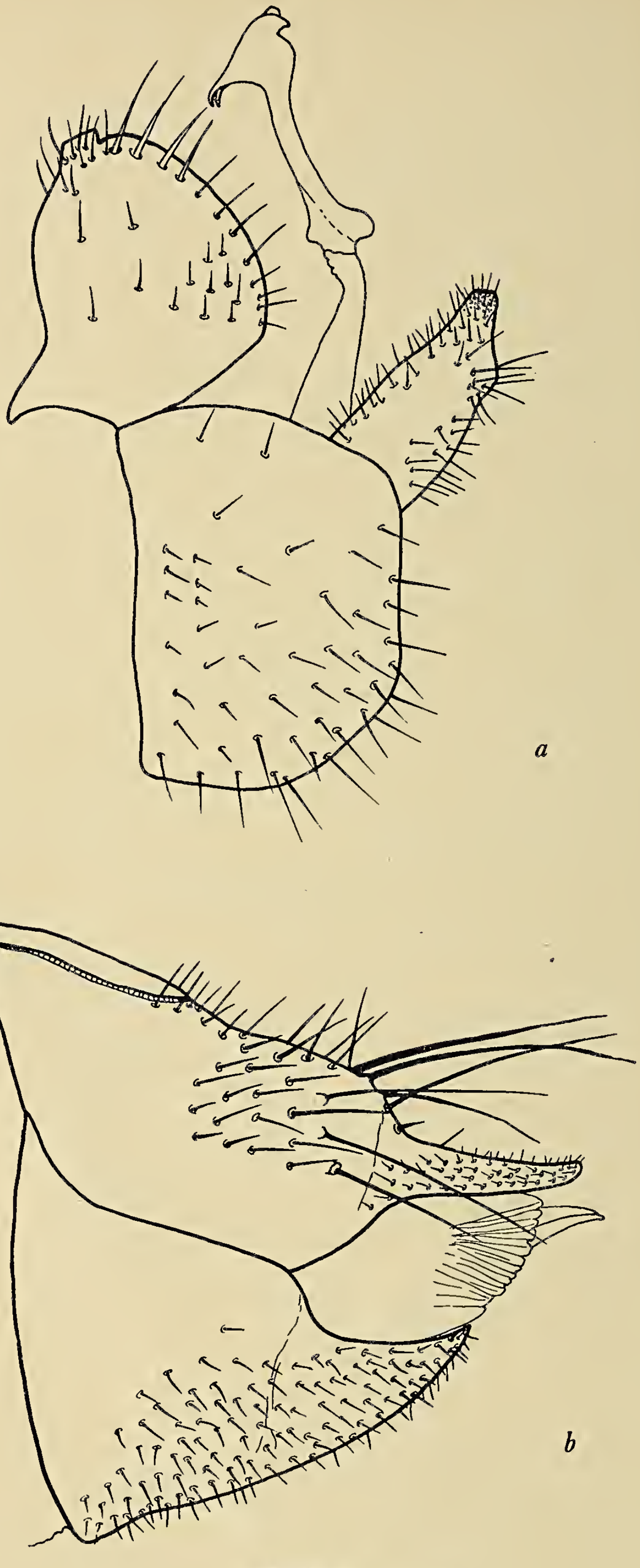

FIG. 21. *Trioza compressa* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

HOST PLANTS: *Olearia arborescens* Cock. and Laing and *O. rani* (A. Cunn.) Druce.

This seems to be closest to *T. subacuta*, *T. doryphora*, and *T. subvexa* but it is readily distinguished by its greater pigmentation, more robust body, larger size, and different genitalia.

Trioza crinita n. sp.

Fig. 22

Length to tip of folded wings 3.5–4.25 mm.

COLOR: General color dark brown with legs and margins of most sclerites buff. Genal processes white, black tipped. Forewings evenly fumate. Many females much less pigmented, of a general buff color. Granular wax deposit prominent on many specimens, especially along sides and on first abdominal tergite.

STRUCTURE: Body moderately robust with sparse, short, stiff pubescence, surface shining, finely rugulose. Head large, slightly narrower than mesoscutum. Vertex strongly impressed discally, caudal margin sharp, raised, smoothly rounded down anteriorly. Genal processes conical, blunt, scarcely divergent, 0.8 as long as vertex. Antennae twice as long as width of head. Eyes large. Postocular areas large. Pronotum strongly depressed below plane of vertex. Forewings large, 2.5 times as long as wide, broadly rounded apically, membrane set with very small points except along veins; Rs long, sinuate, marginal cells equal. Hind wings thickly set with large points. Metatibiae with serrate basal carina, 1 outer and 3 inner apical spines.

Male genitalia large. Proctiger with small apical epiphysis, very broadly produced caudad, with marginal fringe of very large setae. Forceps shorter than proctiger; in lateral view slender, slightly enlarged before apex then caudal margin oblique to blunt apex; in caudal view stout, nearly straight except incurved and black at tips, touching basally; in dorsal view tips blunt. Aedeagus as figured. Female genital segment large, as long as rest of abdomen; dorsal valve with strong hump bearing tuft of large setae, apical third styliform with large retrorse points; ventral valve strongly compressed from apex almost to base along ventral side, forming a straight keel, apical portion heavily sclerotized and thickly set with short retrorse spines.

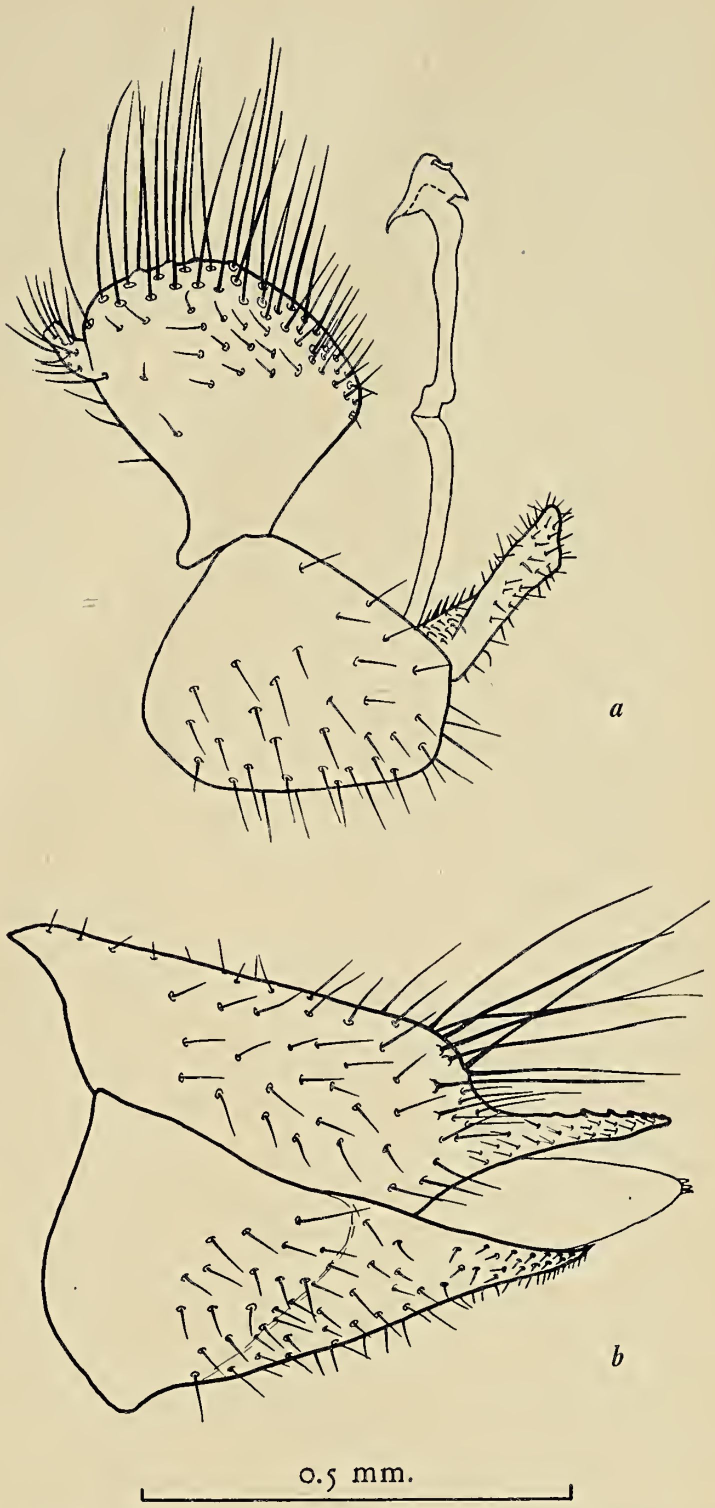

FIG. 22. *Trioza crinita* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

HOLOTYPE, male, allotype, female, 10 male and 7 female paratypes swept from *Olearia ilicifolia* about 1 mile below the Homer Tunnel in the upper Hollyford Valley, January 23; numerous additional males and females taken from the same host near Tokanui, February 3, and Arthur's Pass, February 5. From a single specimen of *Olearia macrodonta* below Fox Glacier, 2 males and 2 females, February 7; (see discussion under *T. compressa*).

HOST PLANT: *Olearia ilicifolia* Hook.

The large size, broad wings, and type of genitalia distinguish this species from all others known except *T. scobina* and *T. latiforceps*, from both of which it differs in color and details of structure.

Trioza scobina n. sp.

Fig. 23

Length to tip of folded wings 3.75–4.50 mm.

COLOR: General color yellowish buff. Abdomen somewhat darker, especially tergites. Forewings yellowish.

STRUCTURE: Body surface rough, shining, with short sparse pubescence. Head large, nearly as wide as mesoscutum. Vertex with deep discal foveae, bulging but not overhanging anteriorly. Genal processes small, divergent, acute, 0.66 as long as vertex. Antennae slightly over twice as long as width of head. Eyes of moderate size, postocular areas large. Pronotum long, vertical, depressed below vertex. Forewings large, very broadly rounded, only slightly more than twice as long as wide, membrane thickened, without points; Rs long, sinuate, marginal cells equal. Hind wings large, thickly set with minute points. Metatibiae with basal serrations, 1 outer and 3 inner apical spines.

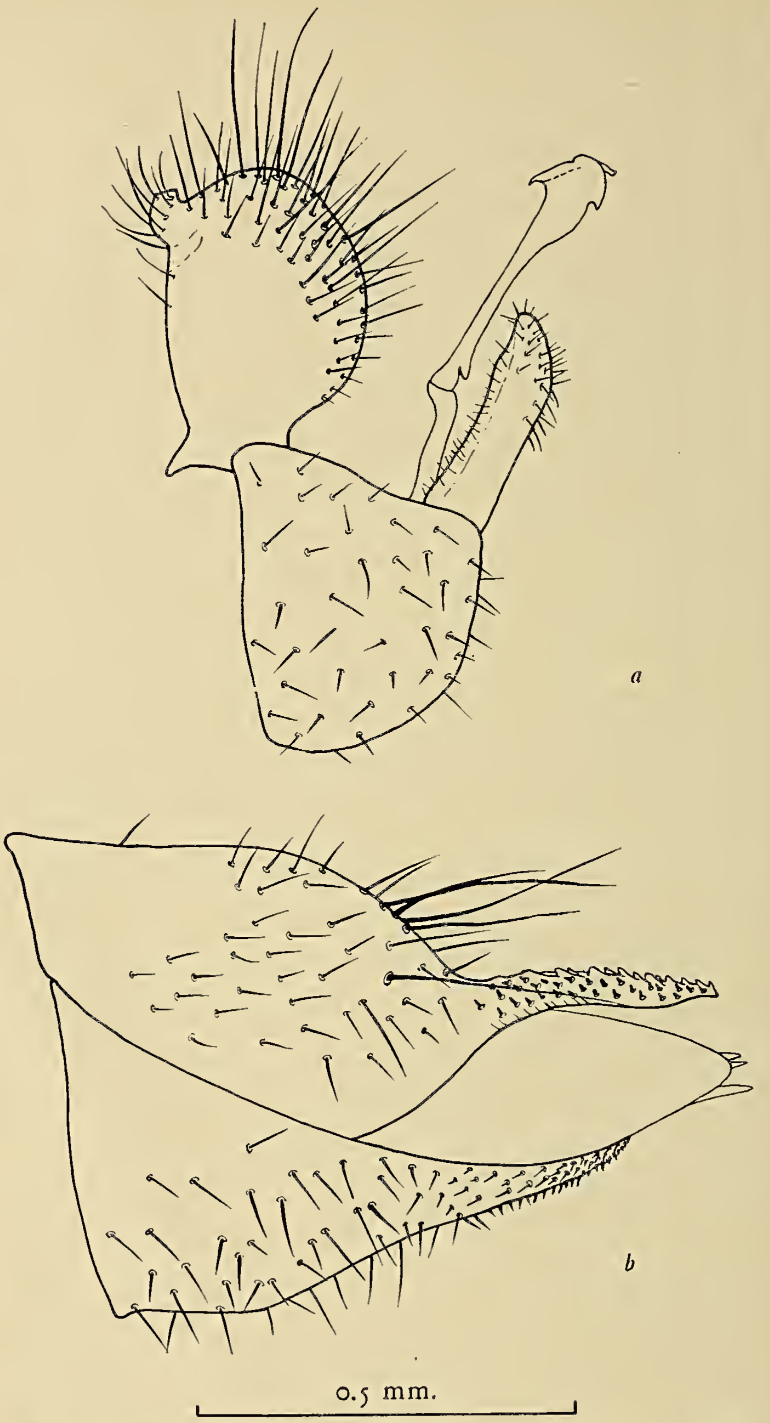

FIG. 23. *Trioza scobina* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

Male genitalia large. Proctiger with small apical epiphysis, very broadly produced caudad, with marginal row of large setae. Forceps shorter than proctiger; in lateral view straight, obliquely narrowed apically, tip blunt; in caudal view stout, nearly straight, incurved apically to sharp tips; in dorsal view apices black tipped, sharp. Aedeagus as figured. Female genital segment large, longer than rest of abdomen; dorsal valve with tuft of large setae, apical third styliform, downcurved, with heavy retrorse sclerotic points; ventral valve nearly as long as dorsal, swollen basally then laterally compressed, apical portion heavily sclerotized, thickly set with fine retrorse spines.

HOLOTYPE, male, allotype, female, numerous male and female paratypes from *Olearia lacunosa*, January 10 and 12, on and near Balloon Hill in the Mount Arthur Tableland area.

HOST PLANT: *Olearia lacunosa* Hook.

Although quite close to *T. crinita* this species is easily distinguished from the latter by the larger size, broader wings, shorter genal processes, the downcurved apical portion of the dorsal valve of the female, and the broader, sharp-pointed male forceps.

Trioza latiforceps n. sp.

Fig. 24

Length to tip of folded wings 3.50–4.25 mm.

COLOR: General color buff. Abdominal dorsum dark brown. Forewings yellowish.

STRUCTURE: Head large, nearly as wide as mesoscutum. Vertex with deep discal foveae, bulging anteriorly. Genal processes short, stout, conical, divergent from base, 0.66 as long as vertex. Antennae twice as long as width of head. Eyes moderate in size. Postocular areas large. Pronotum long, vertical. Forewings large, broadly rounded, 2.5 times as long as wide, membrane thickened, without points; Rs long, somewhat sinuate, marginal cells equal. Hind wings large, thickly set with minute points. Metatibiae with small, serrate, basal carina, 1 outer and 3 inner apical spines.

Male proctiger long, moderately produced caudad, with moderate-sized fringing setae. Forceps shorter than proctiger; in lateral view narrow basally, caudal margin straight, anterior margin strongly swollen to truncate apex; in caudal view stout, nearly straight to incurved, black-tipped apex; in dorsal view tips broad, shallowly excavate, forming slight black tooth at each end. Female genital segment longer than rest of abdomen, large basally, apical half attenuate, styliform; dorsal valve with tuft of long setae on basal portion, apical portion straight to sharp apex with very small retrorse spines near tip; ventral valve shorter than dorsal, apical styliform portion with short setae, upturned at tip.

HOLOTYPE, male, allotype, female, 3 male and 6 female paratypes, near Balloon Hill, January 10 and 12, on *Olearia lacunosa*.

HOST PLANT: *Olearia lacunosa* Hook.

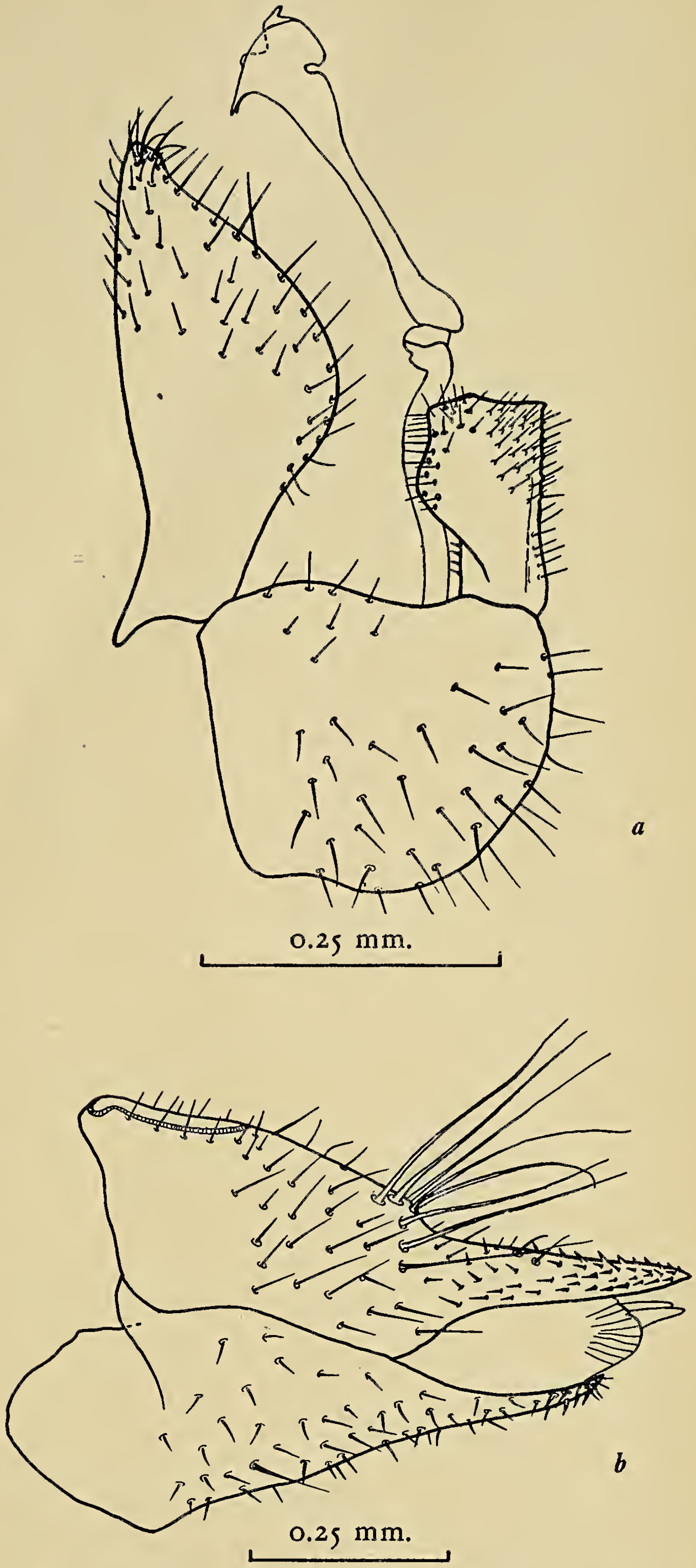

FIG. 24. *Trioza latiforceps* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

In sweeping the plants of *Olearia lacunosa* from which this species, *T. scobina*, and *T. flavida* were taken, it was obvious that two species were present because of the difference in size and color. This species and *scobina* were not distinguished, however, until the material was mounted and examined under the microscope. Although in size and color it does resemble *scobina*, it is readily distinguished from it by the smaller and more slender wings, the much stouter genal processes, and by the genitalia which are quite different in both sexes.

Trioza flavida n. sp.

Fig. 25

Length to tip of folded wings 2.75–3.75 mm.

COLOR: General color yellow. Abdomen yellow or greenish yellow. Genal processes white. Forewings yellow.

STRUCTURE: Body surface rugose, almost glabrous dorsally. Head large, slightly wider than mesoscutum. Vertex impressed discally, smoothly rounded to genae. Genal processes short, stout, divergent, scarcely over 0.5 as long as vertex. Antennae slightly less than twice as long as width of head. Eyes of moderate size. Postocular areas large, swollen. Pronotum vertical. Proepisterna strongly produced. Forewings broadly rounded, 2.5 times as long as wide, membrane with scattered points except along veins, veins setate. Hind wings large, set with minute points. Metatibiae with very small basal serrations, 1 outer and 3 inner apical spines.

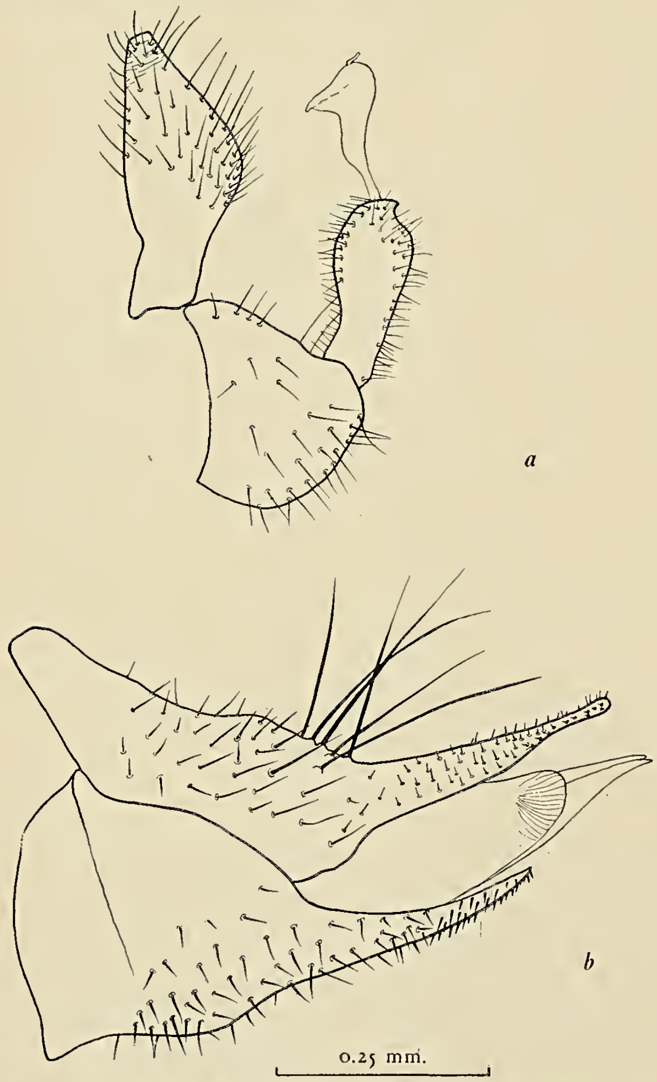

FIG. 25. *Trioza flavida* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

Male proctiger long, slender, moderately swollen caudad. Forceps large, about 0.5 as long as proctiger; in lateral view broadly clavate; in caudal view slender, arched to black tips; in dorsal view tips black, sharp, curved caudad. Female genital segment large, longer than rest of abdomen, valves large basally, slender and styliform apically; dorsal valve without conspicuous hump on basal portion, with tuft of long setae, apical portion straight, slightly swollen at tip, with minute, straight setae; ventral valve shorter than dorsal, styliform portion upcurved, with short stout setae.

HOLOTYPE, male, allotype, female, many male and female paratypes, taken from *Olearia lacunosa* near Balloon Hill, January 10 and 12.

HOST PLANT: *Olearia lacunosa* Hook.

This species, taken in company with the two preceding, was the most abundant at the time of collection. It is quite distinct from the other two although it seems to be nearer *latiforceps* than any of the other species known.

Although a few nymphs were found in pseudogalls formed by the curling of the edges of young leaves, I am unable to assign them to any one of the three species present on this host.

Trioza australis n. sp.

Fig. 26

Length to tip of folded wings 3.5–4.0 mm.

COLOR: General color cinereous with orange to brown markings on vertex, mesodorsum, and legs. Abdomen brown. Tip of proctiger and forceps black. Wings hyaline. Body more or less completely covered with powdery wax.

STRUCTURE: Body surface finely rugose and with short sparse pubescence. Head narrower than mesoscutum. Vertex with strong discal foveae, bulging over antennal bases and genae anteriorly. Genae produced as slender, conical, diverging processes, slightly over 0.8 as long as vertex. Antennae 1.7 times as long as width of head. Eyes large. Postocular area large. Pronotum narrow, below plane of vertex. Forewings large, almost 3 times as long as wide, apex narrow but not acute, entire membrane, except along veins, with prominent points; Rs very long, sinuate, cubital cell slightly larger than medial. Hind wings 0.66 as long as forewings with similar points on membrane and on veins. Metatibiae with serrate basal carina, 1 outer and 3 inner apical spines.

Male genitalia large. Proctiger strongly swollen caudad, evenly narrowed to oblique apex. Forceps shorter than proctiger; in lateral view narrow basally, then swollen as figured, narrowed and incurved apically to blunt tips; in caudal view stout, nearly straight, tips incurved, sharp, touching. Female genital segment large, longer than rest of abdomen, swollen basally, slender apically; dorsal valve with apical third attenuate to sharp apex, with very short setae except for prominent cluster dorsally on basal portion; ventral valve shorter than dorsal, attenuate portion thickly set with short, stout setae, apex acute.

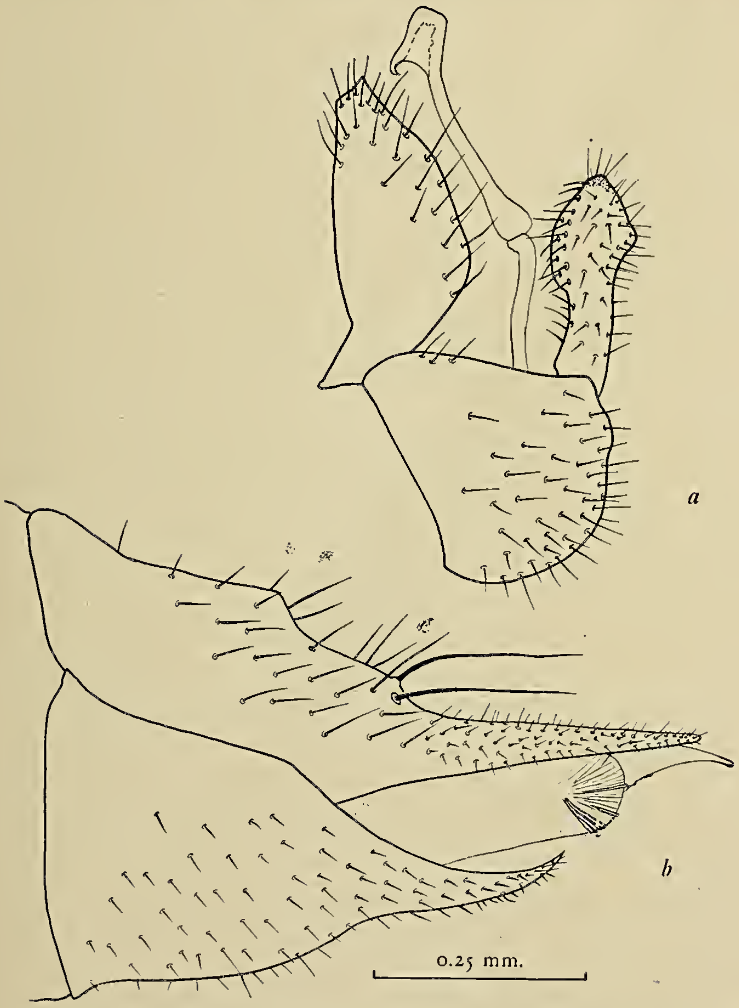

FIG. 26. *Trioza australis* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

HOLOTYPE, male, allotype, female, numerous paratypes, Oban, Stewart Island, January 29, 30, 31, where they were abundant on the common muttonbird plant.

HOST PLANT: *Senecio rotundifolius* Hook.

Trioza styligera (Ferris and Klyver)

1932 *Powellia styligera* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 46, pl. 10.

Two females collected in sweeping alpine vegetation on Mount Ruapehu, at 4,700–5,000 feet, November 17, seem to be this species. Although the area was examined carefully on November 17, and the same and other similar areas were combed during the succeeding week, no additional specimens could be obtained.

The host is completely unknown but I think it probable that it is a species of *Olearia*, *Senecio*, or one of the closely related Compositae, as the species shows very marked similarity in structure to *T. australis* and other related forms.

Trioza fasciata (Ferris and Klyver)

Fig. 27

1932 *Powellia fasciata* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 45, pl. 11.

Length to tip of folded wings 4.0–4.5 mm.

COLOR: Variable from uniformly green or light brown to very dark brown with scutellum and legs green, abdominal tergites margined with red. Forewings uniformly embrowned or with various dark brown fascia with remainder of membrane transparent, usually either entire posterior margin of wing broadly brown or two fascia across basal half.

STRUCTURE: Additions to the original description are: Head as wide as mesoscutum. Hind wings short, 0.6 as long as forewings. Metatibiae with serrate basal carina.

Male proctiger broadly produced caudad, with small apical epiphysis. Forceps very

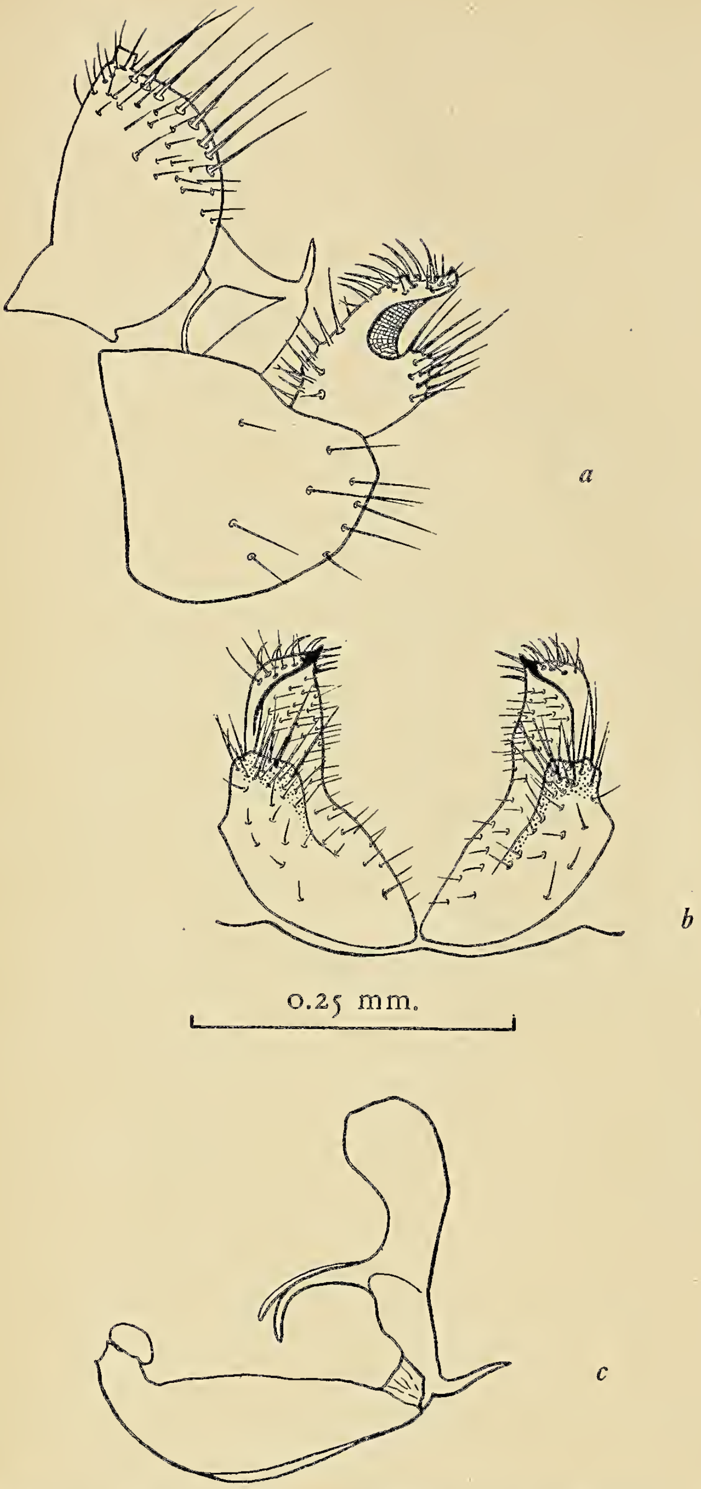

FIG. 27. *Trioza fasciata* (Ferris and Klyver). *a*, Lateral aspect of male cauda; *b*, caudal aspect of claspers; *c*, lateral aspect of aedeagus.

short, deeply cleft. Aedeagus of remarkable form as figured.

HOST PLANT: *Mühlenbeckia australis* Meissn.

Several specimens of this very beautiful species were taken at Paiaka, the Phormium Research Station near Foxton, with the assistance of R. A. Cumber of that station, on May 4. They were beaten from a tangle of *Mühlenbeckia australis* and *Urtica* growing in a *Phormium* swamp. First-stadium nymphs were found in small galls formed by the curling under of the edge of the leaf of the *Mühlenbeckia*. Additional specimens were taken by R. A. Cumber at the same spot May 5, 1950, at which time they were very abundant.

Trioza decurvata (Ferris and Klyver)

1932 *Powellia decurvata* Ferris and Klyver, New Zeal. Inst., Trans. 63: 37, 39, 44, pls. 9, 10.

Numerous specimens of this species were taken from its host plant, *Dracophyllum urvilleanum* var. *montanum* of Cheeseman (which is now considered to be a hybrid between *D. recurvum* and *D. longifolium*), on the slopes of Mount Ruapehu during the latter half of November at altitudes ranging from 3,000 to 4,700 feet. The only discrepancy between these specimens and the description and figures of Ferris and Klyver is in the length of the genal processes, which they record as fully as long as the vertex, but which are not over 0.8 as long in any of the specimens at hand. Additional data are: Length to tip of folded wings, 2.75 to 3.25 mm. Some individuals more or less green, especially the abdomen, others with forewings dark brown. Membrane of forewings thickened, points very small.

Trioza obfusca (Ferris and Klyver)

1932 *Powellia obfusca* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 46, pls. 9, 11.

No specimens of this species were taken unless the following form is identical. (See the discussion under *T. obscura.*)

Trioza obscura n. sp.

Fig. 28

Length to tip of folded wings 2.75–3.00 mm.

COLOR: General color brown, dark dorsally, lighter ventrally. Forewings brown, with small dark-brown anastamosing spots, to very dark, almost black. Hind wings dark brown along anal margin.

STRUCTURE: Body surface shining, punctate, with extremely short, sparse pubescence, no wax apparent on any of the specimens at hand. Head and pronotum strongly deflexed. Head narrower than mesoscutum. Vertex flat, with circular discal impressions, slightly bulging anteriorly. Genal processes stout, conical, somewhat divergent, 0.7 as long as width of head. Eyes rounded. Postocular sclerites poorly developed. Thorax broad and rather flat. Pronotum not depressed below plane of vertex. Forewings rounded apically, with apex in costal half, 2.6 times as long as wide, membrane thickly set with very minute points, masked by pigment; Rs long, nearly straight, cubital cell much larger than medial. Metatibiae with small basal serrations, 1 outer and 3 inner apical spines.

Male genitalia large. Proctiger with prominent apical epiphysis, broadly rounded from base. Forceps shorter than proctiger; in lateral view broad, anterior margin rounded; in caudal view moderately stout, slightly arched to sharp black tips, caudal surface concave. Female genital segment large, almost as long as rest of abdomen, unusually thick dorsoventrally; dorsal valve with distinct hump bearing long setae, apex slender, blunt, with numerous short, slender setae, ventral line straight; ventral valve shorter than dorsal, acute apically.

HOLOTYPE, female, allotype, male, 1 female and 2 male paratypes, from *Hebe angustifolia*, Takaka Hill, near Nelson, January 8 and 13. Additional paratypes: 2 from *Hebe angustifolia*, Whangamoa Saddle, near Nelson, January 16; 1 Tawhai Falls, Tongariro National Park, November 26, swept from mixture of shrubs; 7 swept from mixed shrubs at edge of *Nothofagus* forest, 30 miles S.E. of Taupo.

HOST PLANT: *Hebe angustifolia* A. Rich. (Probable.)

I think that this is probably *T. obfusca* (Ferris and Klyver). It is certainly very close to the latter, but I find four discrepancies between the specimens at hand and the description and figures of *obfusca*. These are: (1) The antennae of this form are barely 1.5 times as long as the width of the head (the range of variation in the specimens at hand being 7.5:8.9 to 7.2:10.7) whereas *obfusca* has antennae "scarcely twice as long as width of head"; (2) the cubital cell of the forewing is larger than in *obfusca;* (3) the abdomen is strongly sclerotized as opposed to "weakly sclerotic" in *obfusca;* (4) the dorsal valve of the female genital segment has a definite hump dorsally, the distance from the anus to the tip is fully twice the length of the anus, the apex is not set with stout retrorse setae as

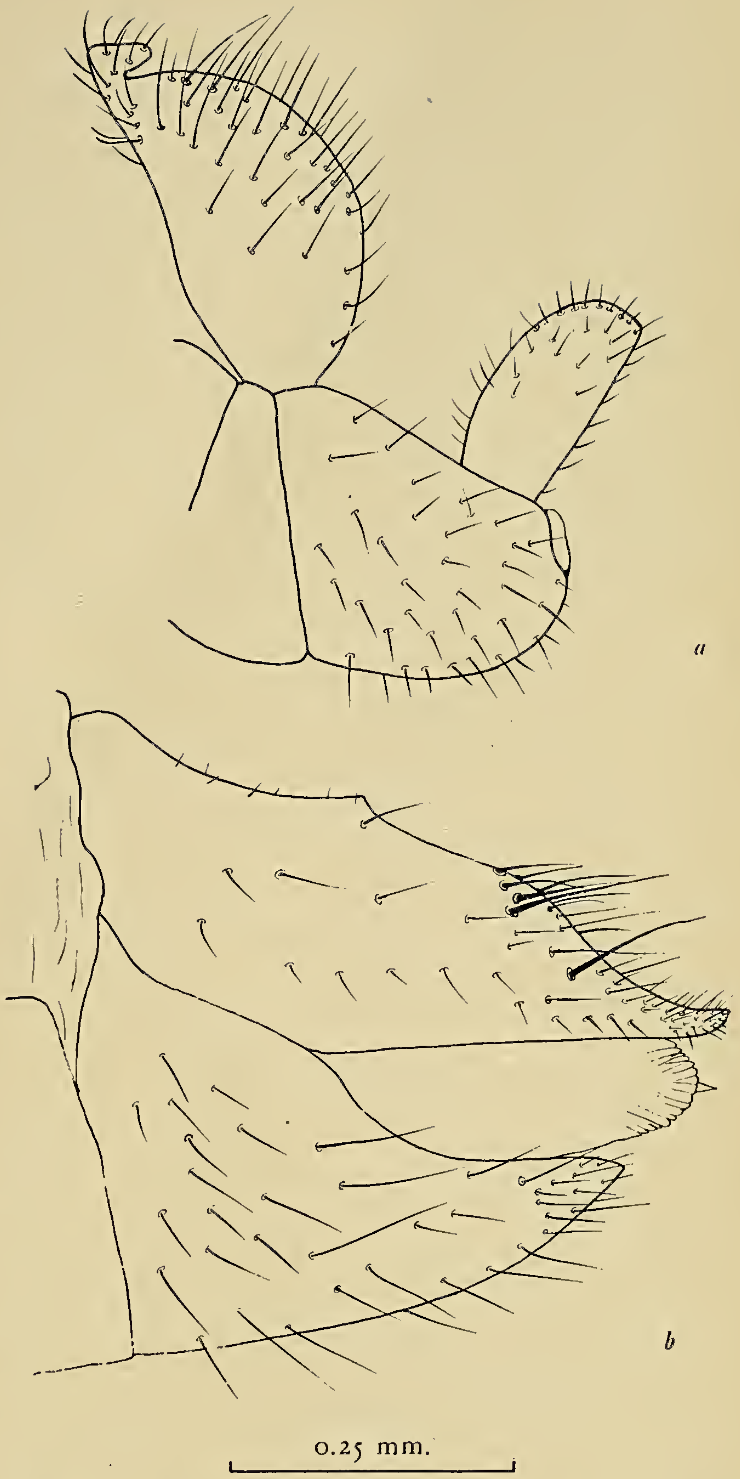

FIG. 28. *Trioza obscura* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

figured for *obfusca* but is as shown in Figure 28.

I am not prepared to assume a degree of error in the work of Ferris and Klyver which would allow ignoring of these differences, rather minor though they be, for I have found their paper to be very accurate. There are, of course, possibly other differences which may be found if the unique type of *obfusca* is ever located for comparison or if future collecting produces additional specimens, especially males. It will be less confusing in this circumstance, I believe, to establish a probable synonym than to designate these specimens as *obfusca*.

Four of the specimens taken on Takaka Hill were taken from a single, rather isolated plant of *Hebe angustifolia* at the edge of a small area of bush on January 8. On January 13 I returned to this plant and obtained two more specimens. Later in the week I captured two more from the same species of plant on Whangamoa Saddle, where I had gone to search for them. In both localities I swept all the surrounding plants in search of additional specimens, without success. In dissecting several of the females, I found that they were gravid; in one specimen an egg was lying in the ovipositor. I think it probable, therefore, that *Hebe angustifolia* is a host. The series taken southeast of Taupo was swept from a tangled mixture of shrubs which included a species of *Hebe* which may be *angustifolia* or *salicifolia* or something else.

Trioza colorata (Ferris and Klyver)

Fig. 29

1932 *Powellia colorata* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 47, pls. 9, 11.

Length to tip of folded wings 2.5–2.75 mm.

One female taken at Arthur's Pass is identical with the one described by Ferris and Klyver. Another taken with her, and hundreds of others taken elsewhere, all differ in having a clear band across the dark forewing from the base of the cubital cell to the costa, wider at the costa, in addition to the two clear areas on the clavus and at the base of the costa. This coloration gives the insects a distinct black and white banded appearance in the net.

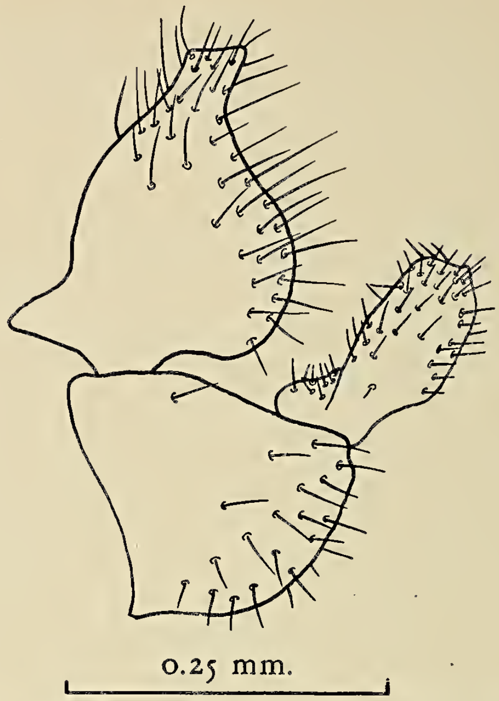

FIG. 29. Lateral aspect of male cauda of *Trioza colorata* (Ferris and Klyver).

The male proctiger is strongly produced caudad. The forceps are shorter than the proctiger; in lateral view broad, narrowed toward base, with broad anterior basal lobe, with small black tooth apically; in caudal view broad, nearly straight, tips sharp, black, incurved.

Many specimens were taken from *Dacrydium biforme* at 3,000 to 4,700 feet on Mount Ruapehu, November 17 to 27; 2 females taken from the same host, Arthur's Pass, February 5; many males and females from *Dacrydium bidwillii*, Balloon Hill, January 10 and 12.

HOST PLANTS: *Dacrydium biforme* Pilger and *D. bidwillii* Hook.

Trioza dacrydii n. sp.

Fig. 30

Length to tip of folded wings 2.5–3.0 mm.

COLOR: General color greenish yellow. Antennae and legs sooty. Veins of forewings black, membrane slightly fumate.

STRUCTURE: Body surface finely punctate. Head wider than mesoscutum. Vertex with

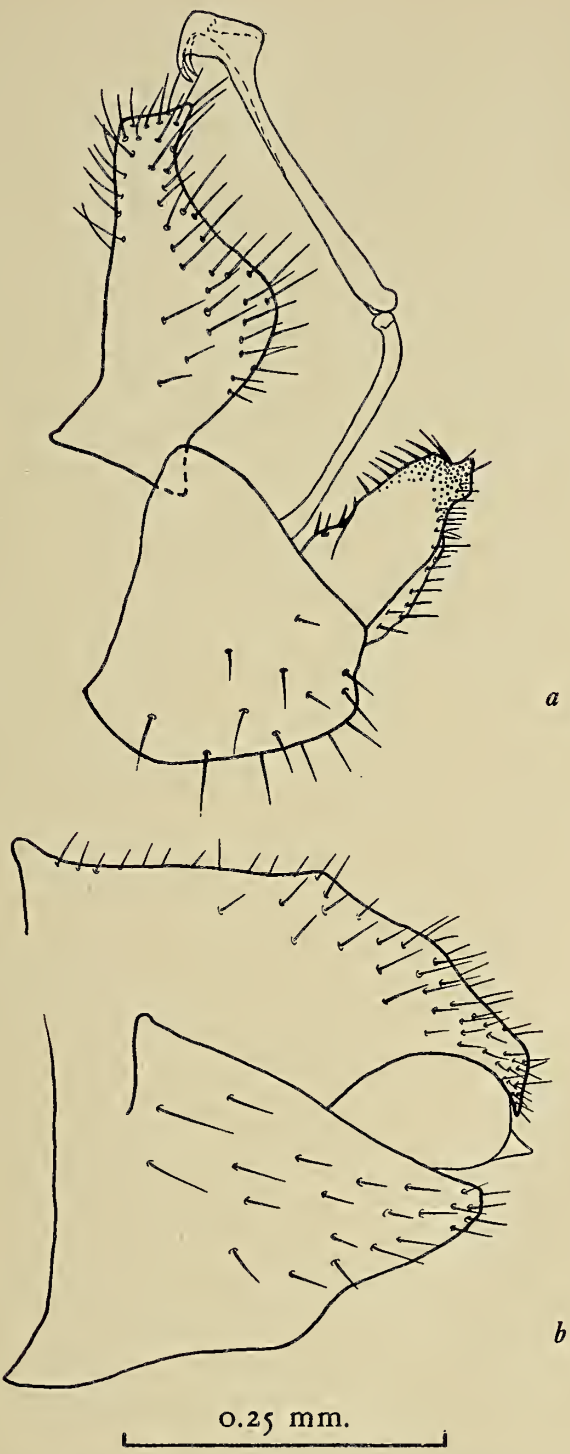

FIG. 30. *Trioza dacrydii* n. sp. *a*, Lateral aspect of male cauda; *b*, lateral aspect of female cauda.

very strong discal impressions, slightly bulging anteriorly. Genal processes conical, divergent from base, 0.6 as long as vertex, longer than medial suture. Antennae twice as long as width of head. Postocular sclerites large, strongly produced caudad. Pronotum short, not strongly depressed. Forewings broadly rounded apically, 2.5 times as long as wide, membrane with fine points in area behind cubitus; Rs moderately long, very slightly sinuate, marginal cells equal. Hind wings short, with prominent points throughout. Metatibiae with serrate basal carina, 1 outer and 3 inner apical spines.

Male proctiger elongate, slightly roundly produced caudad, apex oblique. Forceps shorter than proctiger; in lateral view stout, sinuate to broad apex, with caudal portion produced as blunt tooth; in caudal view stout, evenly arched, with mesal angle of apex produced as small, blunt, black tooth; in dorsal view almost evenly narrowed to blunt black tips. Female genital segment shorter than rest of abdomen, stout; dorsal valve strongly downcurved to truncate apex; ventral valve nearly as long as dorsal, blunt.

HOLOTYPE, male, allotype, female, numerous paratypes, Mount Ruapehu, November 17, taken from *Dacrydium biforme* at 3,700–4,700 feet. Additional paratypes from the same locality on various dates in November and from Arthur's Pass, February 5, swept from the same host.

HOST PLANT: *Dacrydium biforme* Pilger.

This species shows no very close affinity to any of the other known New Zealand forms.

Trioza adventicia n. sp.

Fig. 31

Length to tip of folded wings 3.0–3.5 mm.

COLOR: General color of males chocolate brown, with white band of wax on first and last abdominal tergites. Forewings very faintly yellow, transparent, small black spot at anal angle. Females with head and thorax lighter brown.

STRUCTURE: Body surface finely punctate, with long sparse setae. Head as wide as mesoscutum. Vertex with sharp discal impressions, slightly bulging anteriorly. Genal processes short, blunt, divergent, 0.5 as long as vertex. Antennae 1.5 times as long as width of head. Thorax not very strongly arched. Pronotum not depressed below plane of vertex, roundly produced caudad medially. Forewings large, narrowed apically and angular, 3 times as long as wide, membrane without points except in small area at base; Rs short, nearly straight, marginal cells equal. Hind wings short,

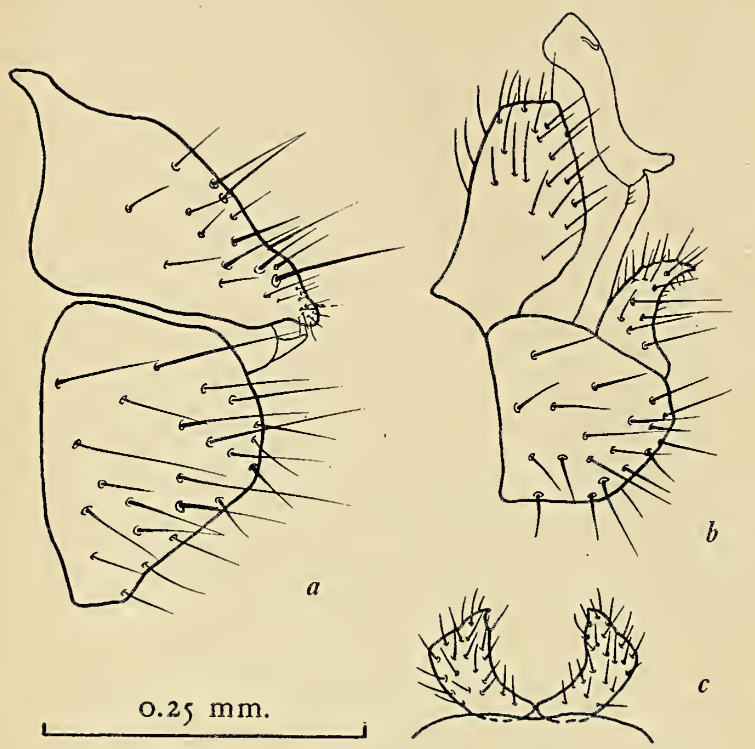

FIG. 31. *Trioza adventicia* n. sp. *a*, Lateral aspect of female cauda; *b*, lateral aspect of male cauda; *c*, caudal aspect of claspers.

scarcely over 0.5 as long as forewing, set throughout with points. Metatibiae with single basal tooth, 1 outer and 2 inner apical spines. Metacoxae slightly raised anteriorly, not spiniform, meracanthi prominent.

Male genitalia small. Proctiger short, broad in lateral view. Forceps very short; in lateral view broad basally, evenly narrowed, apically turned caudad to sharp tip; in caudal view stout, roundly truncate apically to blunt black mesal tooth. Female genital segment short; dorsal valve steep to blunt tip; ventral valve very short, truncate.

HOLOTYPE, male, allotype, female, numerous paratypes, nymphs and eggs taken from plants of *Acmena floribunda* in Nelson, September 19, October 20, and March 7. The feeding of the nymphs on the young leaves causes small pits, rolling of the leaf edges, and discoloration as described by Froggatt in infestations of *T. eugeniae* in Australia (Froggatt, 1901: 284.

HOST PLANT: *Acmena floribunda* D. C. [*Eugenia floribunda*].

This species is apparently an immigrant probably with its host. What its original home may be is problematical. It belongs with the group of species which Crawford segregated as *Megatrioza*. It resembles *T. curta* (Ferris and Klyver) and *T. eugeniae* Froggatt. It is readily distinguished from both by the presence of only 2 inner apical spines on the metatibiae. I have examined the type specimens of *T. eugeniae* Froggatt and find, as expected, that his statement that there are stout spines on the protibiae is an error; they are on the metatibiae as in other members of the genus, one on the outer and three on the inner margins.

Trioza curta (Ferris and Klyver)

1932 *Powellia curta* Ferris and Klyver, New Zeal. Inst., Trans. 63: 38, 39, 45, pls. 8, 10.

Specimens of this species were taken in abundance (all stages) from young sprouts of pohutukawa on Rangitoto Island, September 30, 1950. Specimens are also in the Plant Diseases Division Collection, same locality, April 30, 1945, M. W. Carter. It is undoubtedly common throughout the range of its host but seems to be limited to the young, tender foliage as none was found on older leaves although the pits formed by the feeding of the nymphs are common thereon.

In general structure and appearance this and the preceding species are very similar. They fall into the group of species which Crawford segregated as *Megatrioza*, based on a series of characters not one of which will hold for the entire group. Most of the species which have been variously referred to *Megatrioza* undoubtedly constitute a natural group, but I do not feel it is worthy of generic status. It may properly be considered a subgenus.

Additional notes on the species:

Length to tip of folded wings 3 mm.

Head wider than mesoscutum. Pronotum long, not depressed. Membrane of forewings with minute points in small basal area. First abdominal tergite with covering of powdery wax. Metatibiae with 1 outer and 3 inner apical spines. Metacoxae somewhat raised anteriorly, not spiniform.

HOST PLANT: *Metrosideros excelsa* Soland.

PAUROPSYLLINAE

This subfamily is poorly defined, largely because of the incomplete state of knowledge of the tropical psyllid faunas in which the majority of the species assigned to this group occur.

Ferris and Klyver assigned a species to each of two genera which have been placed here. One of these species, *Pauropsylla meyersi* Ferris and Klyver, appears to be correctly placed in the subfamily although it must be assigned to a distinct genus.

As Ferris and Klyver were apparently unfamiliar with the genus *Gyropsylla* [*Metaphalara*] in which they placed the other species (*Metaphalara zealandica* Ferris and Klyver), there is some doubt as to whether it was properly placed.

ATMETOCRANIUM new genus

The characteristics which will serve to distinguish this genus from *Pauropsylla* and other known genera are: absence of the coronal suture; covered frons; lack of genal processes; much reduced propleura; metacoxae small, without meracanthi; lack of claws on proximal segment of metatarsi; dichotomously branching veins in the forewing; pterostigma present; only five pairs of abdominal spiracles; valves of female genitalia fused.

GENOTYPE: *Atmetocranium meyersi* (Ferris and Klyver) = *Pauropsylla meyersi* Ferris and Klyver.

Atmetocranium myersi (Ferris and Klyver)

1932 *Pauropsylla myersi* Ferris and Klyver, New Zeal. Inst., Trans. 63: 58, pl. 15.

This peculiar species was very completely described and figured by Ferris and Klyver. A series of 11 males and females was taken from kamahi beside the road below Waituhi Trig, November 26, one other specimen was taken the same day several miles nearer Taumarunui. Other specimens were reared from galls on kamahi, taken at Catlins, December 18, 1946, by G. B. Rawlings. This is a true gall-forming species, the nymphs developing under the bark of twigs of the kamahi. They cause the twig to swell into an elongate gall. Upon maturity the bark ruptures above each insect and the adults emerge. The abandoned galls resemble cicada oviposition injury superficially. G. B. Rawlings first supplied me with this information and some specimens of adults reared from the galls. With his assistance I was able to find the nymphs beneath the growing bark near Rotorua. The kamahi seems to be more heavily infested the further south one goes. Small trees on Stewart Island were deformed as a result of recurrent attacks.

The specimens at hand are somewhat larger than those which Ferris and Klyver had. The present ones range to 3.4 mm. in length to tip of folded wings.

Unfortunately I was unable to determine whether this or a related species occurs on the related tawhero, *Weinmannia sylvicola*.

HOST PLANT: *Weinmannia racemosa* Linn.

That this species is congeneric with *Pauropsylla verticis* Crawford and *P. depressa* Crawford, as was suggested by Ferris and Klyver, is highly doubtful even though these species also lack the coronal suture. This specialization is found in at least one other species, *Levidea lineata* Tuthill, a North American species which shows no other similarity to *Atmetocranium*.

Genus GYROPSYLLA Brèthes

1921 *Gyropsylla* Brèthes, La Plata Univ. Nac., Facult. Agron., Rev. 14: 87

1925 *Metaphalara* Crawford, Brotéria, Ser. Zool. 22(11): 60.

Three representatives of this genus are known in addition to the New Zealand species which Ferris and Klyver placed here. Of these, one is North American, the others South American. Crawford stated, when erecting the genus *Metaphalara*, that it appeared to be between Pauropsyllinae and Aphalarinae. Its relationships are still quite unknown.

Gyropsylla zealandica (Ferris and Klyver)

1932 *Metaphalara zealandica* Ferris and Klyver, New Zeal. Inst., Trans. 63: 60, pl. 15.

It was very disappointing to be unable to obtain any specimens of this species, even in the type locality. Ferris and Klyver apparently had seen no specimens of the genus and assigned *zealandica* to it with some doubt. As has been indicated in the discussion, if this species is properly placed in this genus, it shows a very definite link to the American fauna.

SPONDYLIASPINAE

A single species of a new genus, *Anomalopsylla*, is placed here, principally on the basis of the structure of the metacoxae.

ANOMALOPSYLLA new genus

STRUCTURE: Head and pronotum strongly deflexed from plane of body. Head wider than mesoscutum. Vertex plane, twice as wide as long, caudal margin straight, medial suture prominent, rounded to genae without suture. Genae not at all produced, not covering frons. Frons visible from below as large triangular sclerite. Antennae of moderate length. Thorax quite flat. Pronotum wide, flat, on same plane as vertex. Propleura equal, covered by mesopleura. Forewings broad, rounded apically, veins strongly raised, membrane vesiculate; media and cubitus with common petiole, cubitus 3-branched, anterior branch not reaching margin, cross vein between M_1 and Rs, pterostigma present, costa with fracture just before R_1, costal area from this point to base of wing perpendicular to remainder of wing. Metatibiae without basal armature, with several small black apical spines. Proximal segment of metatarsi with 2 black claws. Metacoxae very weakly developed, without meracanthi, with minute protuberance at base of coxal cavity.

GENOTYPE: *Anomalopsylla insignita* n. sp.

The very peculiar species placed here is most closely related to *Tainarys* Brèthes of any of the genera known to me. It differs from this South American genus principally in the venation of the forewing. Both *Anomalopsylla* and *Tainarys* resemble the principal group of endemic Australian forms in the nature of the metacoxae and are therefore tentatively referred to the subfamily Spondyliaspinae although the degree of relationship is doubtful. It seems quite possible that, when the South American fauna is adequately known, a distinct subfamily may be distinguished which will include these two forms.

Anomalopsylla insignita n. sp.

Fig. 32

Length to tip of folded wings 1.25–1.60 mm.

COLOR: General color cinereous with brown markings, principal ones 2 pairs of dots on vertex, transverse stripe from antennal sockets to median ocellus, 2 pairs of dots on pronotum, broad median vitta on prescutum, 2 on mesoscutum. Abdomen brown dorsally. Forewings semiopaque, membrane faintly brown, with irregular light brown mottling, veins with dark brown spots.

STRUCTURE: Body surface finely punctate, shining, with very short, sparse pubescence. Head wider than mesoscutum. Vertex flat, twice as wide as long, with small, shallow discal impressions, posterior margin straight, anterior margin slightly excavate medially, rounded down. Genae not at all produced, not covering frons. Frons visible as distinct triangular sclerite. Clypeus small. Antennae 1.2 times as long as width of head. Eyes globular, projecting, even with posterior margin of vertex. Postocular area small. Thorax quite flat. Pronotum deflexed, but not depressed, wider than mesoscutum, almost as wide as head. Forewings short, strongly tapered in basal third, flaring toward apex, rounded, apex on costal side of center, veins very large and strongly raised, membrane thickened, vesiculate; costal margin fractured just proximad of R_1, costal margin from this

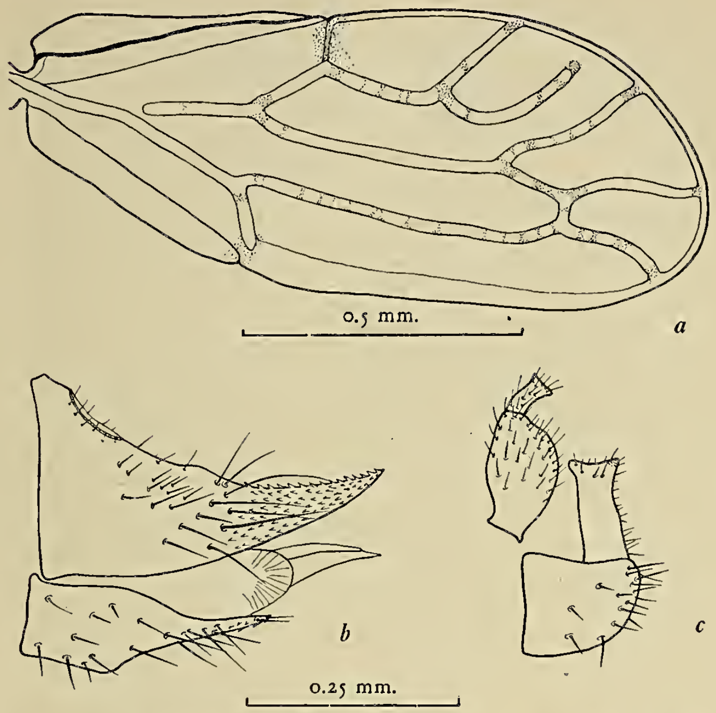

FIG. 32. *Anomalopsylla insignita* n. g., n. sp. *a*, Forewing; *b*, lateral aspect of female cauda; *c*, lateral aspect of male cauda.

point to base broadly bent outward at 90 degrees; long, thickened, pterostigmal area not bounded by distinct vein, Rs long, reaching to near apex, petiole of M and Cu not attached to basal vein, Cu_1 branched, anterior branch not reaching margin, cross vein between Rs and M_1 (an additional cross vein between M_4 and the anomalous branch of Cu_1 is common in the specimens at hand), cubital cell larger than medial. Hind wings well developed. Metatibiae very long, slender, without basal armature, continuous row of 8 black spines on anterior margin of apex.

Male proctiger large, rectangular, with distinct anal segment. Forceps shorter than proctiger; in lateral view straight, nearly parallel-sided to slightly flaring, truncate apex; in caudal view simple, slightly arched to blunt black tips; in dorsal view tip broadly excavate. Female genital segment larger than rest of abdomen; dorsal valve strongly upturned to sharp apex, apical portion thickly set with small retrorse spines; ventral valve shorter than dorsal, acute, with small retrorse spines at apex.

HOLOTYPE, female, allotype, male, numerous adult and nymphal paratypes taken from *Shawia* [*Olearia*] *paniculata*, The Glen, near Nelson, March 7; one female paratype, same locality, January 16.

HOST PLANT: *Shawia paniculata* Forst.

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Descriptions and Redescriptions of the Hawaiian Octocorals Collected by the U. S. Fish Commission Steamer "Albatross." (1. Alcyonacea, Stolonifera, and Telestacea.)[1]

FREDERICK M. BAYER[2]

DURING THE PREPARATION of the report on the Gorgonacea of Bikini, it became necessary to study also the other northern Pacific octocorals in the collections of the U. S. National Museum, mostly obtained by the U. S. Fish Commission steamer "Albatross" during its Hawaiian cruise (1902) and during two cruises to Japanese waters (1898 and 1906). It was immediately evident that many of the specimens from these collections had been incorrectly identified—so many, in fact, that a complete revision of both the Japanese and the Hawaiian collections, as reported upon by C. C. Nutting (1908, 1912), seemed highly desirable. Toward this end, the entire Hawaiian collection of Octocorallia (except the Pennatulacea) was reviewed and reidentified, and will now be redescribed in a series of short papers, of which this is the first. The present part covers seven species and one subspecies in the orders Alcyonacea, Stolonifera, and Telestacea. Of these, one is a correction of specific determination, one is a generic reassignment, and three are reallocations at the ordinal level.

Order ALCYONACEA

Family *ALCYONIIDAE*

Anthomastus fisheri n. sp.

Figs. 1, 2

Anthomastus steenstrupi Nutting, 1908: 555.
Not *Anthomastus steenstrupi* Wright and Studer, 1889: 243, pl. 41, fig. 8.

DIAGNOSIS: Stalk thick, short (½ to ⅔ of total height); capitulum spheroidal; autozooid calyces 3–4 mm. across, low, with margins slightly raised; siphonozooids about 9 in 4 sq. mm. Spicules of outer surface of stalk and capitulum as spiny stars and short rods; of interior of stalk, long, slender rods or needles.

DESCRIPTION: The largest specimen is about 23 mm. tall. The stalk is 8–9 mm. in diameter and 12 mm. in length; it is attached by a thin, membranous expansion to a small rock. The capitulum is spheroidal, 12 mm. high and 14 mm. in diameter. It bears about 25 large autozooids which in life probably exceeded 5 mm. in height; these are partially retractile into low calyces which have slightly raised rims. In contraction, the upper part of the anthocodiae project from the bottom of crater-like pits in the capitulum. Between the autozooids, numerous siphonozooids occur; these are seen as small verrucae with simple orifices, slightly raised above the capitulum surface. About 9 siphonozooids occur in an area of 4 sq. mm. The outer wall of the stalk and the surface of the capitulum contain a superficial layer of short, spiny stars, usually with a transverse girdle, which reach about 0.06 mm. in length and 0.05 mm. in width (Fig. 1 *f*); under the layer of stars is a layer of rods which are practically smooth except for a few conical spines, most numerous near their ends (Fig. 1 *e*); these rods attain a length of 0.32 mm., occasionally more. In the interior of the stalk there are similar but longer, more spinose rods (Fig. 1 *d*) often exceeding 0.4 mm. in length. The anthocodial walls contain the spiny, star-like sclerites, many of

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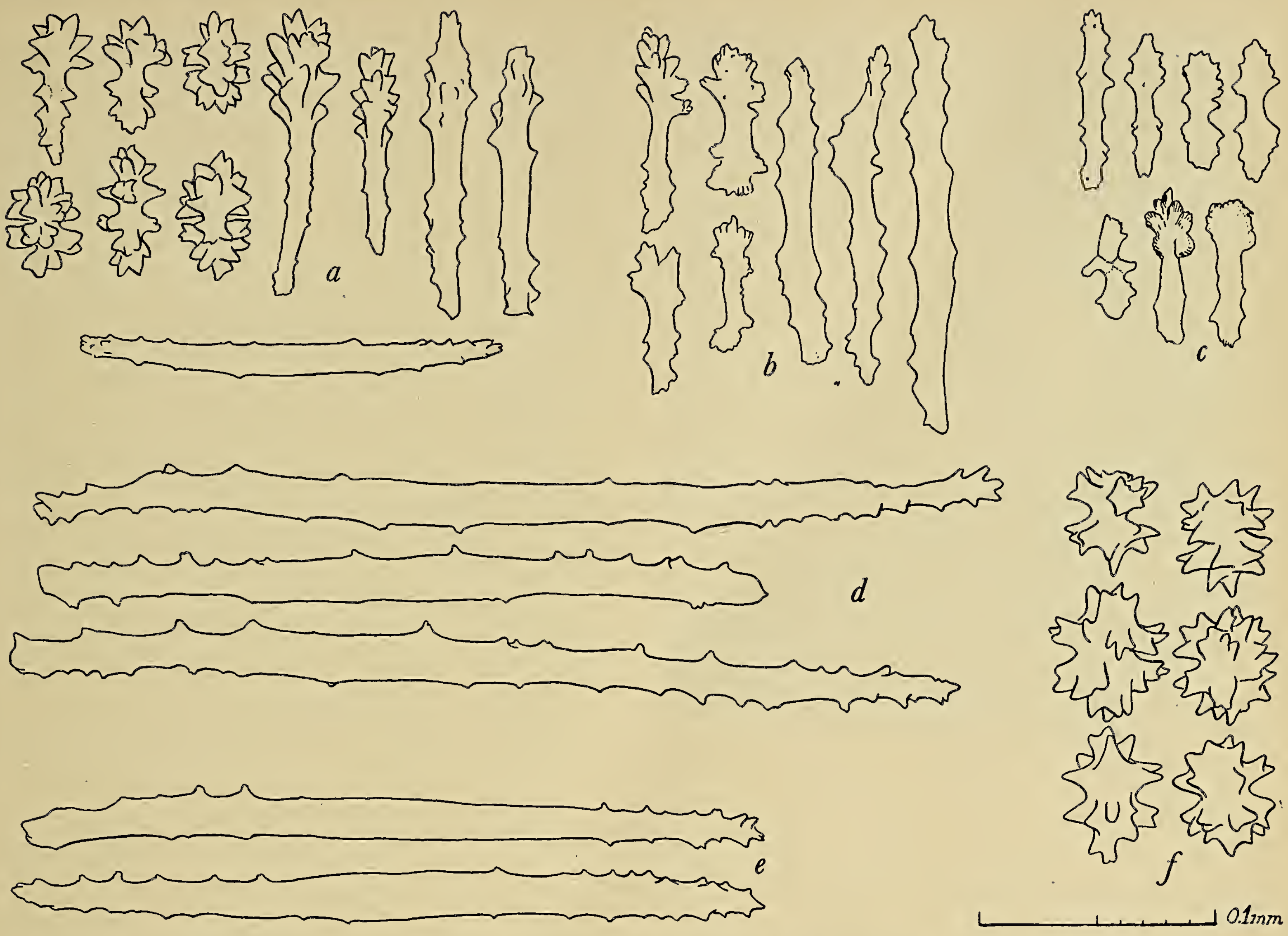

FIG. 1. *Anthomastus fisheri* n. sp. Spicules: *a*, of anthocodial wall; *b*, of tentacles; *c*, of pharynx; *d*, of canal walls of stem interior; *e*, rods of stalk wall; *f*, stellate bodies from outer surface of stalk and capitulum. Scale applies to all figures.

which have the median waist elongated, together with rods and spiny-headed clubs (Fig. 1 *a*). In the tentacles there are flattened rods which often have a club-like expansion at one end (Fig. 1 *b*), and in the gullet there are smaller, flattened spiny rods, often with one or both ends expanded (Fig. 1 *c*).

The color of the colony in alcohol is "ferruginous" (Ridgway); the spicules are practically colorless by transmitted light, but appear pale amber in color by reflected light.

TYPE: U.S.N.M. No. 49623. South coast of Oahu: Honolulu Light bearing N. 2° E., 2.4 miles distant, in 211–253 fathoms, fine coral sand; bottom temperature 47.4°F.; March 27, 1902 ("Albatross" station 3810).

PARATYPE: U.S.N.M. No. 22560. Between Maui and Molokai Islands: Mokuhooniki Islet bearing N. 8°30′ E., 4.8 miles distant, in 143–122 fathoms, coral sand, shell, and foraminifera; bottom temperature 59.7°F.; July 23, 1902 ("Albatross" station 4101).

RECORD: N. W. coast of Oahu: Kahuku Point bearing N. 83° E., 9 miles distant, in 195–241 fathoms, coral sand and foraminifera; bottom temperature 55.1°F.; July 25, 1902 ("Albatross" station 4115).

REMARKS: *Anthomastus steenstrupi* Wright and Studer, with which Nutting erroneously identified one of these Hawaiian specimens, differs from *A. fisheri* n. sp. in spiculation and in form of the colony. The new species has more slender, needle-like spicules and more compact, stellate sclerites, and its capitulum is spheroidal, whereas that of *A. steenstrupi* is "very slightly convex" (Wright and Studer) on the upper surface. *Anthomastus fisheri* resembles *A. granulosus* Kükenthal (1910: 14, pl. 1, fig. 3), but that species differs in its granular spheres and double spheres, and in

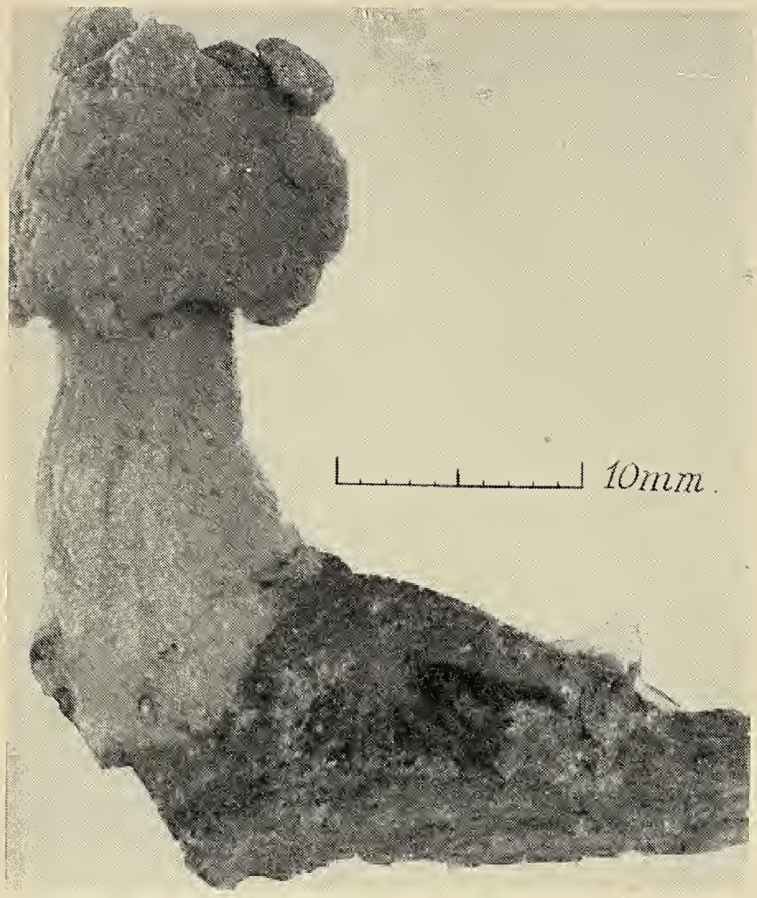

FIG. 2. *Anthomastus fisheri* n. sp. The type colony.

the absence of long needles. *A. fisheri* was taken from depths intermediate between those at which *A. steenstrupi* (565 fathoms) and *A. granulosus* (11–110 fathoms) were found.

It is a pleasure to dedicate this species to Dr. Walter K. Fisher, noted authority on hydrocorals, who was one of the naturalists on the Hawaiian cruise of the "Albatross."

Family *SIPHONOGORGIIDAE*

Siphonogorgia alexanderi (Nutting)

Fig. 3

Spongodes alexanderi Nutting, 1908, U. S. Natl. Mus., Proc. 34: 555, pl. 41, fig. 3; pl. 47, fig. 2.

DESCRIPTION: The loosely branched colony bears on its upper parts scattered zooids which are most crowded at the twig tips. The anthocodiae are protected by shelf-like verrucae which consist of two projecting groups of spicules. There is a wide crown of about six rows of transverse spicules; each of the eight points above the crown consists of one pair of large, unequal, bent spindles together with a small accessory pair. The outer stem walls

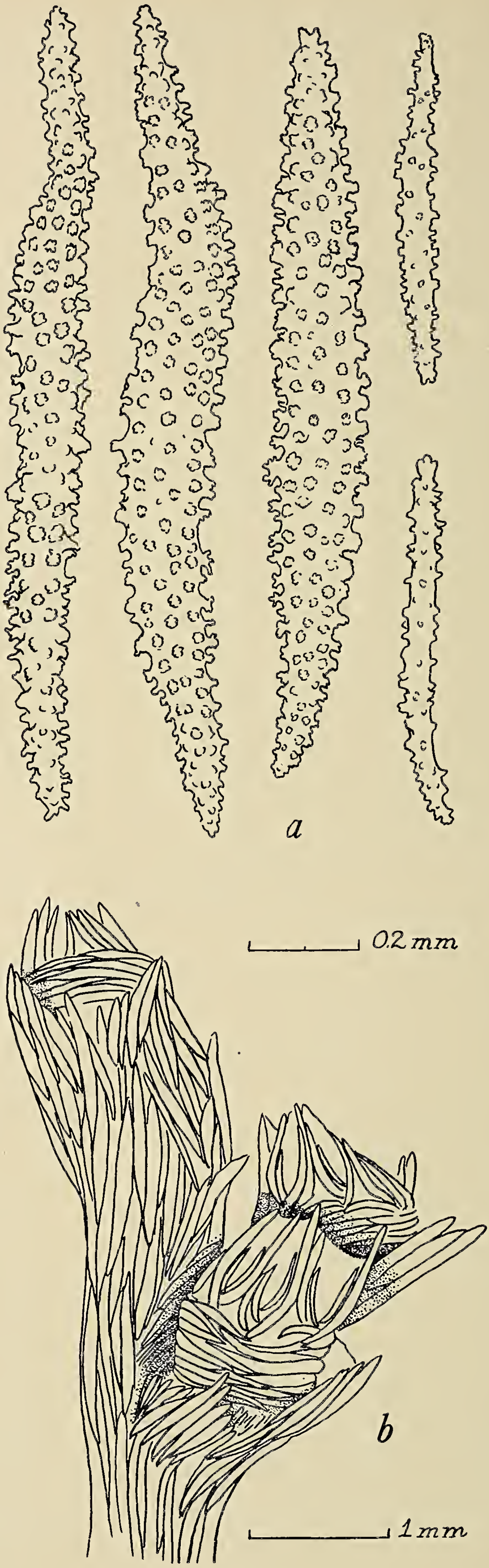

FIG. 3. *Siphonogorgia alexanderi* (Nutting). *a*, Spicules; *b*, twig tip.

contain long, somewhat bent, tuberculate spindles reaching 1.5 mm. in length; those of the inner canal walls are smaller and more slender. Color (in alcohol) white; usually all spicules white, sometimes those of the crown and points pink.

TYPE: U.S.N.M. No. 25361. Between Maui and Molokai Islands: Mokuhooniki Islet bearing N.8°30′E., 4.8 miles distant, in 143–122 fathoms, coral sand, shell, and foraminifera; bottom temperature 59.7°F.; July 23, 1902 ("Albatross" station 4101).

REMARKS: *Siphonogorgia alexanderi* seems to approach *S. variabilis* Hickson, originally described from the Maldive Islands, and may eventually prove to be the same. The differences between many of the published species of *Siphonogorgia* are so vague that only by a complete revision can their status be decided.

Siphonogorgia (?) **collaris** Nutting
Fig. 4

Siphonogorgia collaris Nutting, 1908, U. S. Natl. Mus., Proc. 34: 556, pl. 41, fig. 4. Thomson and Dean, 1931, Siboga Exped. Monog. 13d: 154.

DIAGNOSIS: Branches thick; calyces tubular, about 3 mm. tall, into which the anthocodiae are fully retractile. Entire surface of branches and calyces covered with large, ill-fitting, thick plates which become more spindle-like near the verrucal margins. Anthocodiae with a wide collaret of about 10 transverse rows of curved spindles, and eight points each consisting of a pair of large spindles and one or two pairs of smaller accessory spindles. In the walls of the stem canals there are smaller, warty spindles.

TYPE: U.S.N.M. No. 25318. Laysan Island Light bearing S.79°30′E., 7.3 miles distant, in 57–79 fathoms, white sand, broken shell, and corallines; bottom temperature 71.1°F.; May 16, 1902 ("Albatross" station 3935).

REMARKS: The single fragment obtained indicates a colony with thick branches, but it may just as well have been an unbranched *Nidalia*-like colony only the top of which was sheared off by the dredge. The tall, tubular calyces with their anthocodiae usually more or less exsert, the surface pavement of large plates, and the thick, digitate branches should render the species recognizable when found again.

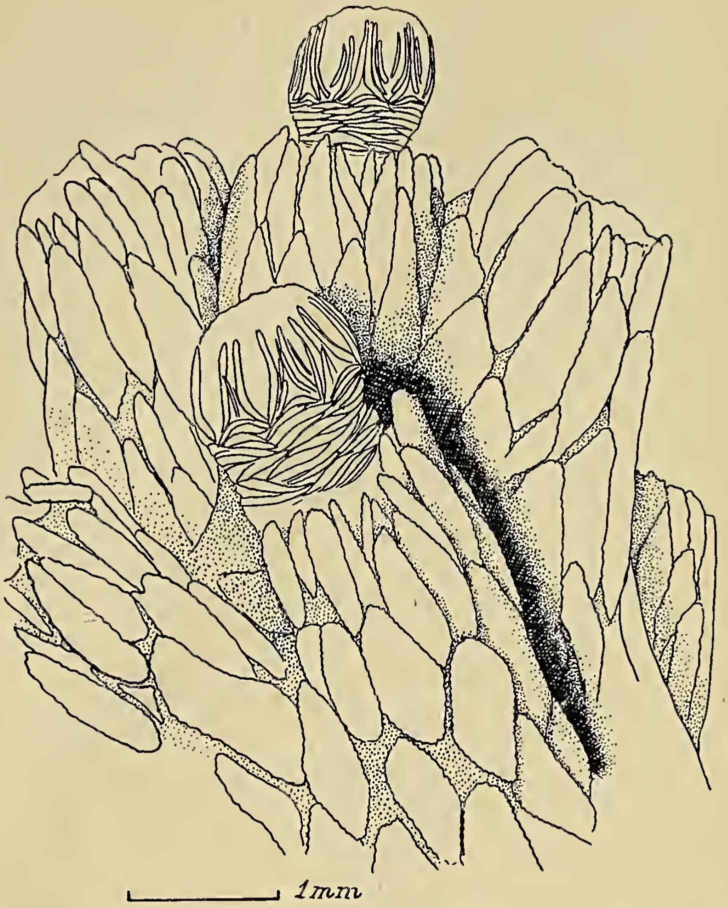

FIG. 4. *Siphonogorgia* (?) *collaris* Nutting. Apex of the type fragment.

Color "coral red" (in life?); in alcohol, ivory white, the soft tissue dull brownish.

Order STOLONIFERA
Family *CLAVULARIIDAE*
Clavularia grandiflora (Nutting)
Fig. 5 *a*

Menella grandiflora Nutting, 1908, U. S. Natl. Mus., Proc. 34: 584, pl. 44, fig. 5; pl. 48, fig. 6. Kükenthal, 1924, Tierreich 47: 185.

DIAGNOSIS: Stolon membranous, filled with bent spindles. Calyces truncate conic, their spicules in the form of spindles arranged obscurely *en chevron* in eight interseptal tracts. Anthocodial neck zone long, with transversely disposed, scattered, small spindles which grade into the strong collaret. Tentacle bases with several pairs of spindles *en chevron*

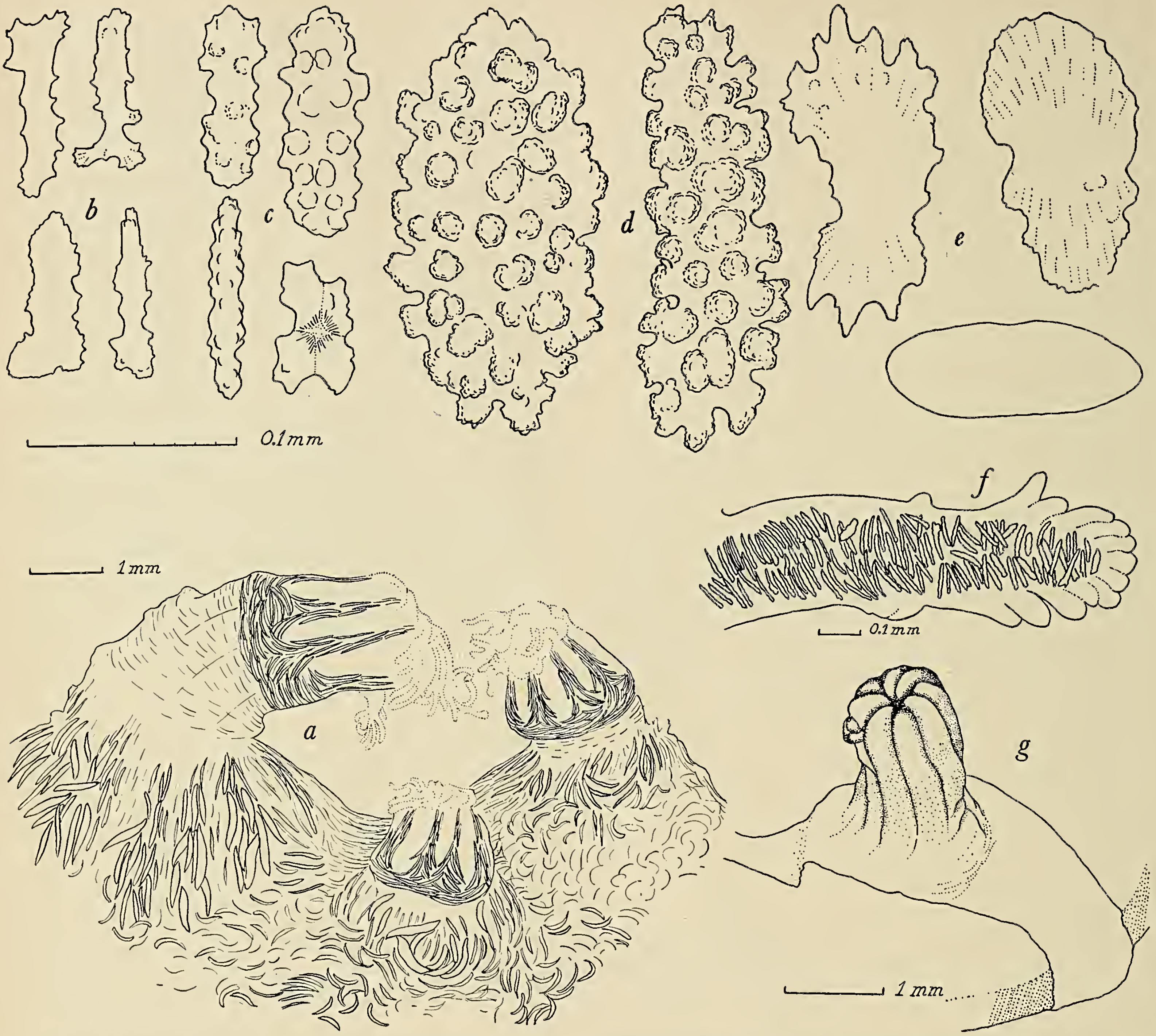

FIG. 5. *a*, *Clavularia grandiflora* (Nutting). Part of membranous stolon with three zooids. *b–g*, *Telestula* (?) *corrugata* (Nutting). *b*, Spicules of the tentacles; *c*, spicules of the neck zone; *d* and *e*, spicules of the stolon and anthostele walls; *f*, a tentacle showing arrangement of spicules; *g*, a zooid.

and continuing in lengthwise arrangement for about one third of the tentacle length, becoming transverse and projecting into the pinnule bases in the distal two thirds of the tentacles.

DESCRIPTION: A membranous stolon bearing numerous zooids completely surrounds part of a dead gorgonian axis. The calyces are low, truncate cones rarely exceeding 3 mm. in height. The anthocodiae usually project considerably, extending 3 or 4 mm. beyond the calyx margins. The spicules of the calyces are stout spindles arranged indistinctly *en chevron* in eight tracts which form points at the calycular margin. The neck zone is extensive and contains small spindles transversely arranged. In the distal part these increase in size and number to form a broad, distinct collaret; below and upon the tentacle bases they assume an *en chevron* arrangement, becoming practically parallel and continuing along the tentacle backs for about one third of their lengths. Thereafter the spindles are small, transversely set, and project into the bases of the long pinnules which are otherwise free of spicules. The stolon is filled with spindles somewhat smaller than those of the calyces; they are frequently rather strongly curved, and are arranged with no regularity at all.

TYPE: U.S.N.M. No. 22590. Vicinity of Kauai Island: Mokuaeae Islet bearing S.54°E., 3.5 miles distant, in 528 fathoms, fine gray sand and mud, bottom temperature 39.6° F.; June 12, 1902 ("Albatross" station 3992).

REMARKS: Professor Nutting must have misinterpreted the strong anthocodial spiculation, the *en chevron* arrangement of the calycular spicules, and the horny axis, which is really no more than a substrate for the colony described. In several places there is a considerable amount of bottom detritus between the stolon and the axis. The iridescence and general appearance of this axis suggest that it may have belonged to a primnoid.

The external features of this species immediately recall Thomson and Dean's *Clavularia ornata* (1931: 13, pl. 14, figs. 1, 5; pl. 21, fig. 2), which differs in having the distal tentacle spicules arranged longitudinally instead of transversely as in *C. grandiflora*, fewer and larger spicules in the anthocodial armature, and longer calyces with somewhat shorter anthocodiae.

Order TELESTACEA

Family *TELESTIDAE*

Genus TELESTULA Madsen

DIAGNOSIS: Octocorals of the Telestacea order, having small slender zooids in which the mesenteries reach down to the stolon only while the zooids are young; the lower part of the coelenteric cavity in the older, more lengthened zooids being partially filled with a mesogloeal tissue. The proximal part of the zooid thus developed into a sort of stem which may constitute the largest part of the zooid and from which secondary zooids may rise. The proximal part of the secondary zooids being developed in a similar manner when they reach a certain size. Secondary zooids of higher order may occur. (Madsen, 1944: 16.)

TYPE SPECIES: *Telestula septentrionalis* Madsen (by original designation).

REMARKS: The genus *Telestula* originally included, in addition to the genotype, *Pseudocladochonus mosaica* Thomson and Dean, and possibly *P. versluysi* Thomson and Dean. To this list should be added: *Telesto ambigua* Nutting, *Clavularia expansa* Thomson and Dean, and *Clavularia spiculicola* Nutting. *Clavularia corrugata* Nutting is also a telestid and is tentatively referable to *Telestula*.

In describing members of this genus, I will refer to the greatly elongated anthostelar part of the zooids as the "body tube," the distalmost margin of this as seen in contracted specimens as the "calycular margin," the introversible part between the anthostele and the tentacles as the "neck zone" which, with the remainder of the retractile part bearing the tentacles, forms the "anthocodia." The spiculiferous mesogloeal tissue occluding the lower part of the gastrovascular cavity will usually be spoken of simply as "intrusion tissue" and its spicules as "intrusion spicules."

Telestula spiculicola (Nutting)

Figs. 6, 7 *a–b*

Clavularia spiculicola (part) Nutting, 1908: 553, pl. 47, fig. 1?; not pl. 41, fig. 1.

DIAGNOSIS: Primary zooids 0.6–0.8 mm. in diameter and up to 50 mm. long, arising from ribbon-like or more spreading stolons; secondary zooids usually present on fully developed primaries. Spicules of anthostelar wall oblong, flattened, strongly warted platelets about 0.2 mm. in length; those of stolons narrower, sparsely but prominently warted; those of intrusion tissue large, branched forms about 0.3 mm. in length.

DESCRIPTION: The colonies arise from stolons which encrust or creep along large sponge spicules. The primary zooids are rather sinuous, less than 1 mm. in diameter, and attain about 50 mm. in length. The primary zooids more than 15 mm. long usually bear a few secondary zooids which are well

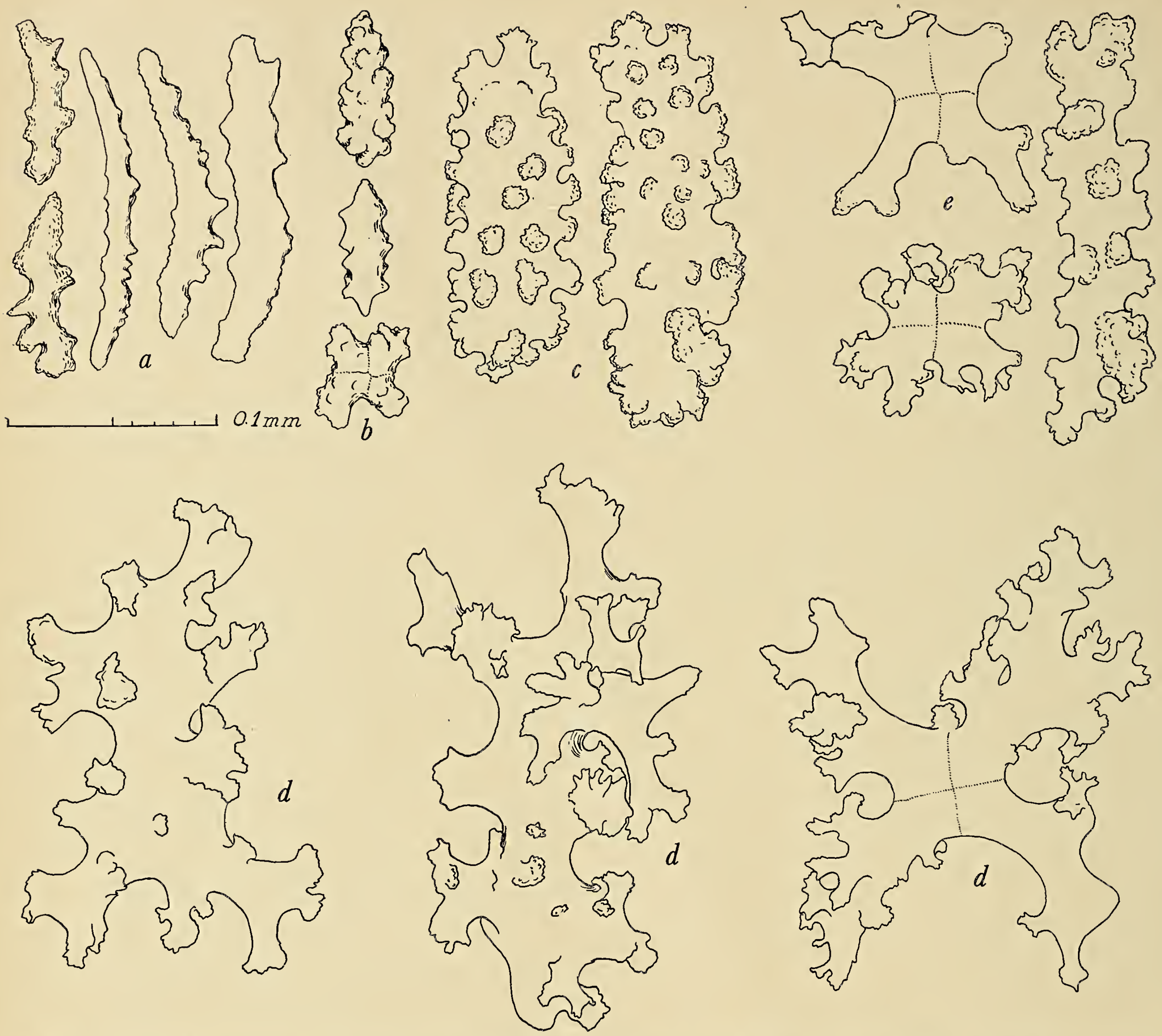

FIG. 6. *Telestula spiculicola* (Nutting). Spicules of: *a*, tentacles; *b*, neck zone; *c*, body tubes; *d*, intrusion tissue; *e*, stolons. Scale applies to all figures.

separated and arise on any side and at no constant angle, although many come off at nearly right angles, subsequently turning upward to about 45°. Well-developed colonies may be a tangled mass of twisted zooids, and there is sometimes fusion of the outer walls where two zooids come in contact, producing a false anastomosis. The primary axial zooids and all subordinates show eight distinct longitudinal ribs which become obscure at the bases of primary zooids and do not continue on the stolons. The outer surface is covered with an exceedingly thin, horny cuticle, and in the gastrovascular cavity there is a horny subepithelial layer which is thickened to form delicate horny ribs along the septal origins. These ribs may be stripped out in dissection just as in *Telesto*. The anthocodiae are fully retractile within the body tubes by virtue of the thin, introversible neck zone in which spicules are less densely distributed; their tentacles are 0.8–0.9 mm. in length and contain a layer of transversely placed narrow rods which are somewhat bent and have irregular margins (Fig. 6 *a*). The tentacle spicules project into the pinnules, which number about 12 on each side of a tentacle. The tentacular deposits are 0.08–0.16 mm. in length. In the neck zone are found short, lumpy rods 0.06–0.08 mm. in length, along with some crosses and other aberrant forms (Fig. 6 *b*). The thick walls of the body tubes contain coarsely warted, blunt rods 0.15–0.2 mm. in length (Fig. 6 *c*). The lower part of the coelenteric cavity beginning about 5 mm. from the mouth is filled in, except for eight longitudinal canals, with spiculiferous mesogloeal intrusion tissue, to form a stem perforated by eight stem canals. It is from this "stem" region that subordinate zooids arise, all of which show similar tissue in their coelenteric cavities as soon as they exceed 7 or 8 mm. in length. The intrusion spicules are branched sclerites about 0.27–0.3 mm. long (Fig. 6 *d*), of the same type found in other species of the genus. The stolons contain slimmer, warted rods, crosses, and branched forms smaller than those in the intrusion tissue (Fig. 6 *e*).

In alcohol the colonies are pale brown or whitish.

TYPE: U.S.N.M. No. 22574. Oahu Island: Diamond Head Light bearing N.7°E., 12.5 miles distant, in 311–337 fathoms, fine gray sand and mud, bottom temperature 43.7°F.; May 5, 1902 ("Albatross" station 3910).

RECORDS: South of Oahu Island: 21°08′ N., 157°43′W., in 351 fathoms, fine white sand, bottom temperature unknown; December 6, 1891 ("Albatross" station 3475). Oahu Island: Diamond Head Light bearing N.23°10′E., 16.4 miles distant, in 289–292 fathoms, gray sand, mud, bottom temperature unknown; May 6, 1902 ("Albatross" station 3914).

REMARKS: This species may be recognized by its very slender body tubes, less than 1 mm. in diameter, and its small, oval spicules. Nutting's paratype consisted of specimens so different that I am here describing them as a distinct subspecies.

Telestula spiculicola robusta n. subsp.

Figs. 7 *c–e*, 8

Clavularia spiculicola (part) Nutting, 1908, U. S. Natl. Mus., Proc. 34: 553, pl. 41, fig. 1.

Specimens (including some paratypes of *spiculicola*) from four stations are distinctly more robust than the type of *Clavularia spiculicola*. The diameter of the body tubes is regularly from 1 to 1.25 mm., even in young primary zooids (Fig. 7 *c–e*). The spiculation in general is very similar, but the major sclerites of the body tubes are distinctly larger (0.35 mm.) and frequently pointed (Fig. 8 *c*), and those of the neck zone (Fig. 8 *b*) are larger and of different form. As in *T. spiculicola* s.s., the tentacles are densely spiculate: short rodlets transversely encircle the rachis of the tentacles, chiefly in two dorsal (aboral) and two adoral tracts, and extend in small groups into the pinnules. The inner and outer stolon spicules are like those of the intrusion tissue and body tubes, respectively, but there are, in addition, more crosses, branched plates, and irregular forms.

TYPE: U.S.N.M. No. 43097. Between Maui and Molokai Islands: Mokuhooniki Islet bearing S.80°30′W., 7.8 miles distant, in 277–284 fathoms, globigerina ooze, bottom temperature 45.2°F.; April 16, 1902 ("Albatross" station 3883).

REMARKS: The figure given by Nutting on plate 41 represents this subspecies, but it is impossible to be absolutely certain from which specimen the illustrated spicules were taken. The spicules are so vaguely depicted as to render the figure worthless.

The subspecies *robusta* can be separated from *Telestula spiculicola* s.s. by the stouter body tubes frequently measuring 1.25 mm. in diameter and 100 mm. in length, and by the larger, usually pointed spicules of the body walls. The differences in the neck zone sclerites can best be seen by comparing the figures of those of the subspecies and of the typical form.

Telestula (?) corrugata (Nutting)

Fig. 5 *b–g*

Clavularia corrugata Nutting, 1908: 554, pl. 41, fig. 2.

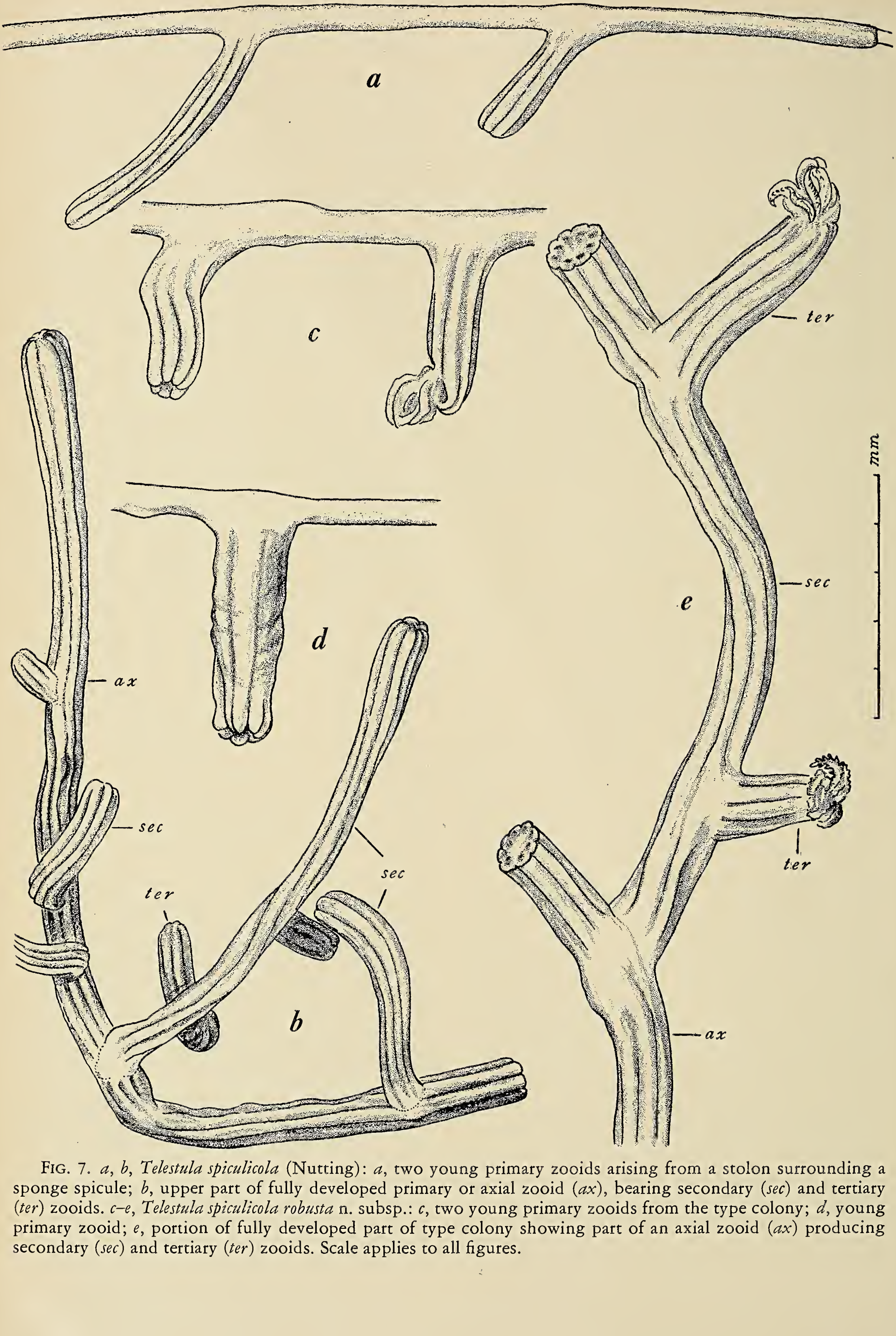

FIG. 7. *a*, *b*, *Telestula spiculicola* (Nutting): *a*, two young primary zooids arising from a stolon surrounding a sponge spicule; *b*, upper part of fully developed primary or axial zooid (*ax*), bearing secondary (*sec*) and tertiary (*ter*) zooids. *c–e*, *Telestula spiculicola robusta* n. subsp.: *c*, two young primary zooids from the type colony; *d*, young primary zooid; *e*, portion of fully developed part of type colony showing part of an axial zooid (*ax*) producing secondary (*sec*) and tertiary (*ter*) zooids. Scale applies to all figures.

DIAGNOSIS: Simple zooids less than 5 mm. tall arising from band-like stolons; walls of anthosteles with eight longitudinal grooves; anthocodiae completely retractile. Spicules of anthosteles and stolons oval, warty plates and smooth scales; anthocodial wall with warty rods and flat rods; tentacles with numerous flat rods transversely arranged and not extending into the pinnules.

DESCRIPTION: The colonies form creeping, ribbon-like stolons about 1 mm. wide, which expand a little at the points where the indi-

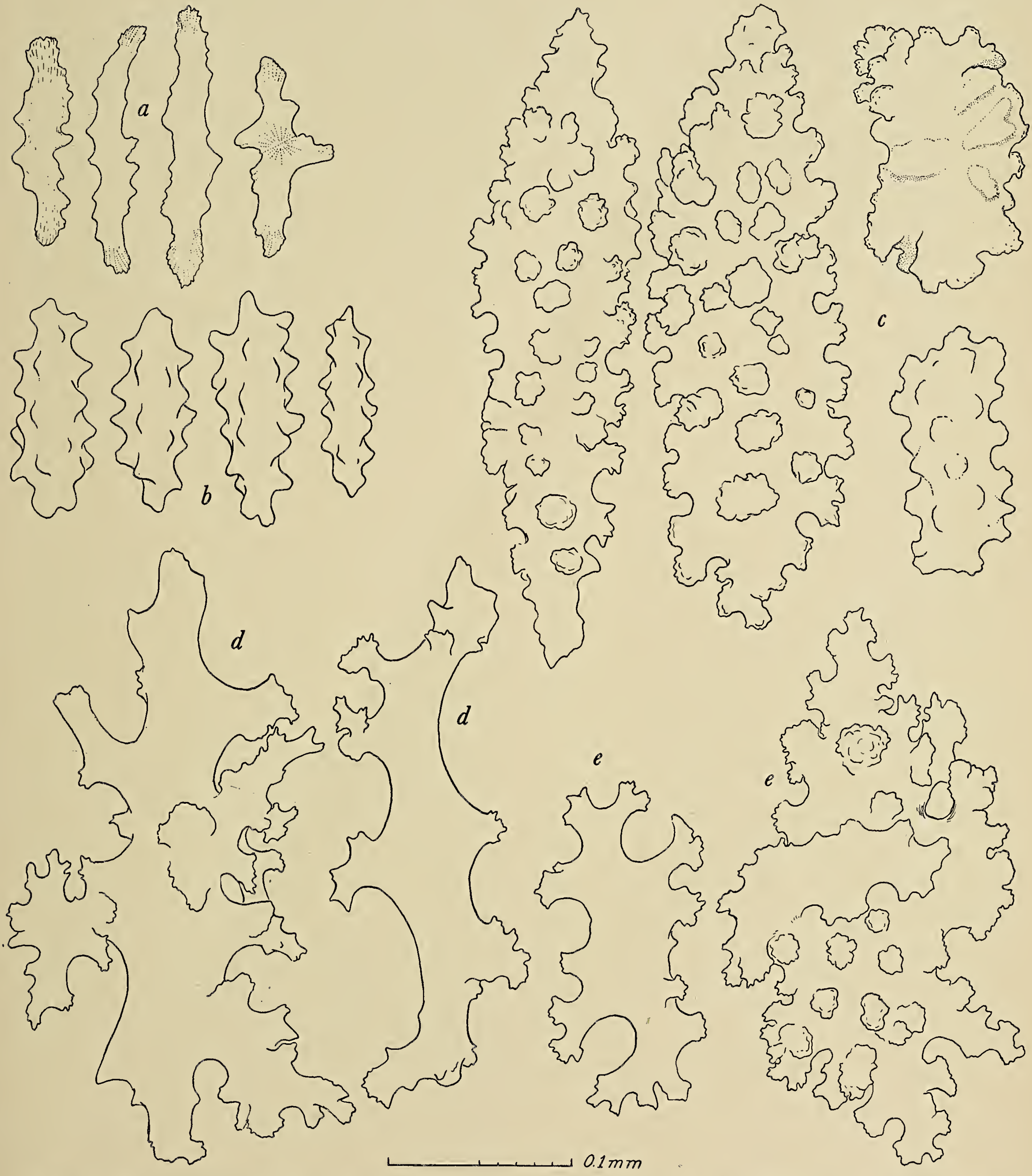

FIG. 8. *Telestula spiculicola robusta* n. subsp. Spicules of: *a*, the tentacles; *b*, the neck zone; *c*, the body tubes; *d*, the intrusion tissue; *e*, the stolon. Scale applies to all figures.

vidual zooids arise. The anthosteles are short, stout tubes with eight narrow, longitudinal grooves separated by broad, rounded ribs (Fig. 5 *g*); the largest is about 4 mm. high and 1.5 mm. in diameter, and none shows evidence of lateral budding. An introversible neck zone permits the anthocodiae to be fully retracted within the anthosteles. The outer surface is covered by a thin, horny cuticle, and the coelenteric cavity evidently has the horny subepithelial layer characteristic of the telestids, since the eight septal ribs of horny matter are present. The stolons and walls of the anthosteles are filled with oval, warty, flat plates (Fig. 5 *d*) and a few practically smooth scales with either entire or notched edges (Fig. 5 *e*). The thin, introversible neck zone contains broad, flat, warty rods, slender, round rods, and a few crosses (Fig. 5 *c*); these are arranged chiefly in eight interseptal tracts and are most numerous near the calycular margin, decreasing in numbers toward the tentacles. The tentacles (Fig. 5 *f*) are about 1 mm. long and are densely packed with flat rods (Fig. 5 *b*) set crosswise but not extending into the pinnules. None of the zooids is long enough to show any intrusion of the coelenteric cavity by spiculiferous mesogloea.

TYPE: U.S.N.M. No. 22594. Alenuihaha Channel between Hawaii and Maui Islands: Kauhola Light bearing S.44°30′E., 16.1 miles distant, in 491–500 fathoms, foraminifera, sand, and rock, bottom temperature 40.2°F.; July 18, 1902 ("Albatross" station 4065).

REMARKS: The telestid affinities of *Clavularia corrugata* are clearly indicated by its spicules and the presence of the characteristic horny layers. Its small, unbranched zooids, the form of its sclerites, and the arrangement of spicules in the tentacles strongly suggest Madsen's genus *Telestula;* unfortunately, none of the zooids is well enough developed to show the mesogloeal intrusion characteristic of that genus. It is possible that *Clavularia corrugata* will prove to be immature *Telestula spiculicola robusta*, in which case the older name will take precedence.

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Properties of the Gray Hydromorphic Soils of the Hawaiian Islands[1]

William R. Gill and G. Donald Sherman[2]

The gray hydromorphic soils of the Hawaiian Islands are dark-colored, poorly drained, sticky plastic clays. These soils owe their morphology to their hydromorphic condition produced by their naturally poor drainage. This poor drainage of the soil has developed poor aeration, reducing conditions, and a reduction of the biological activity, which has prevented the full influence of all soil-forming factors essential to normal soil development.

The gray hydromorphic soils are characterized by a horizon that is mottled gray, brown, and yellow by periodic waterlogged conditions. Cline *et al.* (in press) have divided this intrazonal soil group into three soil families, based on the degree of expression of the hydromorphic characteristics. The soils belonging to the Honouliuli family are the least hydromorphic. They have a grayish-brown, clayey B horizon that is mottled below 18 to 20 inches. The water table is generally not near the surface, and the mottling appears to be the result of impeded downward movement of water rather than a water table. The soils belonging to the Kalihi family are more strongly hydromorphic. The mottling in these soils occurs immediately below the A_1 horizon. The soils of the Kaloko family are the wettest of the group. Mottling appears in the A_1 horizon, and these soils have a water table near the surface most of the year.

The gray hydromorphic soils are found on the islands of Kauai, Oahu, Molokai, and Maui. They have developed on the islands which are the oldest geologically. They are usually found at the lower elevations on these islands and are associated with well-drained soils in the advanced stages of weathering—the latosols. The gray hydromorphic soils have properties which make them similar to the paddy soils (water-logged soils) and to the dark magnesium clays (tropical black soil) of the semi-arid regions. All of these soils (gray hydromorphic, paddy, and dark magnesium clay) exhibit similar physical properties in that they are sticky plastic clays.

The sticky plastic properties of the gray hydromorphic soils make their management very difficult. The most probable reasons for the extreme sticky and plastic nature of these soils are, first, the nature and percentage of clay in these soils, and, second, the presence of a condition in the soil which would cause the soil to exist in a deflocculated condition. This latter condition has been noted in many locations where the amount of exchangeable sodium in the soil has been high. Observations (Von Kreybig, 1935) indicate that when the amount of exchangeable magnesium in a soil is very high, and the sum of the exchangeable calcium plus exchangeable magnesium approaches 100 per cent saturation of the soil, the properties of the soil will be similar to those of a "sodium soil."

Usov (1937) described soils in Russia, having more than 30 per cent of their exchange capacity filled with magnesium, which are plastic and exhibit other "sodium soil" characteristics, including a decrease in the percolation rate. Kudrin and Rozanov (1940) reported a magnesium sierozem which was derived from both high magnesium parent materials and high magnesium ground waters. Such soils possessed a poor physical structure, low porosity, and a generally poor physical condition. Von Kreybig (1935), while studying Hungarian soils, found that 20 to 25 per cent magnesium saturation produced soil properties which were similar to those of soils having a high sodium saturation.

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[1] A part of a reasearch project by the senior author in partial fulfillment of the requirements for a Master of Science degree at the University of Hawaii. Published with the approval of the Director of the University of Hawaii Agricultural Experiment Station, Honolulu, Hawaii, as Technical Paper No. 245. Manuscript received November 16, 1951.

[2] Former graduate student and chairman, respectively, Department of Soils and Agricultural Chemistry, University of Hawaii.

Several workers have reported evidence of magnesium salinization in Hawaiian soils. The Hawaiian soils have developed on basaltic rocks which are very rich in olivine, a magnesium-iron silicate. This would provide a source of magnesium for ground waters which would ultimately find their way to the areas of restricted drainage. McGeorge (1930) pointed out that exchangeable magnesium was increasing in certain soils where the irrigation water contained appreciable amounts of magnesium salts. Hance and Stewart (1927) reported a low calcium–magnesium ratio in certain poorly drained Maui soils which have a high base saturation. This would indicate the presence of magnesium salts. Sherman *et al.* (1947) showed that dolomitization occurs in certain calcareous semi-arid Hawaiian soils where the ground water is rich in magnesium salts. Results of the soil research work at the University of Hawaii have established that, when a soil has more than 30 per cent of its exchange capacity occupied by magnesium, and the sum of the exchangeable calcium plus exchangeable magnesium amounts to more than 90 per cent of the exchange capacity, the soil will exist in a dispersed condition. All soils possessing this relationship are black, sticky plastic clays. The soils of the gray hydromorphic group are of this type.

The purpose of this investigation is to study the factors which give rise to the plastic properties of the gray hydromorphic soils. The influence of such factors as cation exchange capacities, per cent magnesium saturation, calcium–magnesium ratios, organic matter content, amount of clay-size particles, and the nature of the clay minerals on the plasticity of the soil were studied in this investigation.

METHOD OF ANALYSIS

Soil samples were collected from typical soils of the three soil families belonging to the gray hydromorphic group. All of the soils used in this investigation were collected on the island of Oahu. Most of the samples were collected from Ewa, areas adjacent to Pearl Harbor, Wailupe, Koko Head, and the windward areas on the north side of Oahu.

The chemical analysis of the soils was made by standard methods. In the determination of exchange capacity and exchangeable cations, neutral normal ammonium acetate solution was used as the replacing agent. The water-soluble salts were removed by leaching the soil with a 40 per cent ethyl alcohol solution until the leachate was free of chlorides and sulfates prior to the ammonium acetate extraction. Alcoholic solutions of ammonium acetate were used on soil samples containing carbonates, according to the procedure described by Magistad and Burgess (1928).

The plastic index or plastic number—the range of soil moisture over which the soil exhibits plastic properties—was determined by the method proposed by Baver (1932). The upper and lower plastic limits were determined by this procedure, and the difference is referred to as the plastic number.

Organic matter was determined in these soils by the method developed by Walkley (1935).

CHEMICAL AND PHYSICAL PROPERTIES OF THE GRAY HYDROMORPHIC SOILS

The cation exchange capacity, exchangeable cations, per cent magnesium saturation, organic matter content, and plastic number of typical soils of the three soil families of the gray hydromorphic group are given in Table

TABLE 1

THE CHEMICAL COMPOSITION OF THE EXCHANGE COMPLEX, ORGANIC MATTER CONTENT, AND MEASUREMENTS OF PLASTICITY OF TYPICAL GRAY HYDROMORPHIC SOILS

Sample	*p*H	Cation exchange capacity	Exchange-able calcium	Exchange-able magnesium	Per cent Mg saturation	Ca:Mg ratio	Per cent organic matter	Per cent soil particles less than .005 mm.	Upper plastic limit	Lower plastic limit	Plastic number
		m.e./100 g.	*m.e./100 g.*	*m.e./100 g.*							
Honouliuli family											
Hon – 1	7.2	12.8	9.0	3.7	28.9	2.43	2.14	49.2	46.5	34.7	11.8
Hon – 2	6.7	11.0	3.4	3.9	35.5	0.87	0.96	54.5	47.1	33.6	13.5
Hon – 3	7.7	15.5	6.3	4.5	29.0	1.40	1.66	66.5	44.7	32.2	12.5
Hon – 4	7.2	12.7	7.2	4.5	36.2	1.60	1.16	70.6	46.6	30.5	16.1
Hon – 5	7.7	21.3	11.6	10.2	47.9	1.14	2.11	71.0	42.4	25.9	16.5
Kalihi family											
Ki – 1	7.3	27.8	16.1	12.9	46.4	1.25	2.41	52.2	45.5	30.0	15.5
Ki – 2	7.3	28.3	14.8	12.6	44.5	1.18	2.24	54.4	45.7	31.4	14.3
Ki – 3	7.4	24.3	15.3	12.4	51.0	1.23	1.70	63.8	46.5	30.8	15.7
Ki – 4	7.6	25.9	14.3	13.0	50.2	1.10	1.36	62.2	48.6	30.5	18.1
Ki – 5	6.9	31.8	7.9	16.7	52.5	0.47	2.69	58.7	57.4	38.8	18.6
Ki – 6	7.1	29.3	10.1	18.6	63.5	0.54	2.80	66.8	60.6	39.2	21.4
Ki – 7	7.8	41.1	18.2	12.4	30.2	1.47	4.99	64.9	62.3	32.5	29.8
Kaloko family											
Ko – 1	7.8	27.8	12.1	16.0	50.4	0.76	1.51	54.9	43.7	28.5	15.2
Ko – 2	7.4	29.4	14.7	14.1	48.0	1.04	2.66	60.5	47.7	30.9	26.8
Ko – 3	6.5	30.6	15.0	12.6	41.2	1.19	2.76	62.2	54.3	30.2	24.1
Ko – 4	7.8	25.4	11.8	16.9	66.5	0.70	2.48	51.2	44.4	28.2	16.2
Ko – 5	7.7	26.3	15.9	12.4	47.1	1.28	2.04	73.9	54.9	30.7	24.2
Ko – 6	7.4	25.9	16.2	12.0	46.3	1.35	2.55	78.2	58.2	33.4	24.8
Ko – 7	5.9	30.2	17.1	10.4	34.4	1.64	3.37	74.9	72.2	41.8	30.4

1. The lowest cation exchange capacities were found in the soils belonging to the Honouliuli family where the range was from 11.0 to 21.3 milliequivalents per 100 grams. The cation exchange capacities of soils of the Kalihi and Kaloko families range from 24.3 to 41.1 milliequivalents per 100 grams, which are much higher than capacities of the Honouliuli soils. Likewise, the per cent magnesium saturation is the lowest in the soils of the Honouliuli family. The range for all soils was from 28.9 to 66.5 per cent. The ratio of exchangeable calcium to exchangeable magnesium was very variable in each soil family and showed little evidence of any real differences.

The organic matter content of the gray hydromorphic soils varies greatly from soil to soil. These soils have the lowest organic matter content of the Hawaiian soils, as most zonal soils of the islands have an organic matter content higher than 3 per cent. In general, the greater the expression of hydromorphic condition, the greater the organic matter content of the soil.

The soil particles less than 5 microns in size make up the major portion of the particles of these soils. Most of these soils have from 40 to 50 per cent clay-size particles. Thus, all of these soils are clays. The clay content was practically the same for the soils of each soil family.

The plastic numbers of these soils ranged from 11.8 to 30.4. The highest values for the plastic number were found for the soils of the Kaloko family and the lowest for the soils of the Honouliuli family. This would indicate that the plastic properties were developed to the greatest extent in the soils having the greatest hydromorphic conditions.

INTERRELATIONSHIP OF PROPERTIES TO PLASTIC NUMBER

The data presented in Table 1 indicate that some of the chemical properties are related to the plastic number. Figure 1 shows the relationship between the cation exchange capacity of the soil and the plastic number. This relationship is very significant. Statistical analysis of the data shows a correlation coefficient of .697.

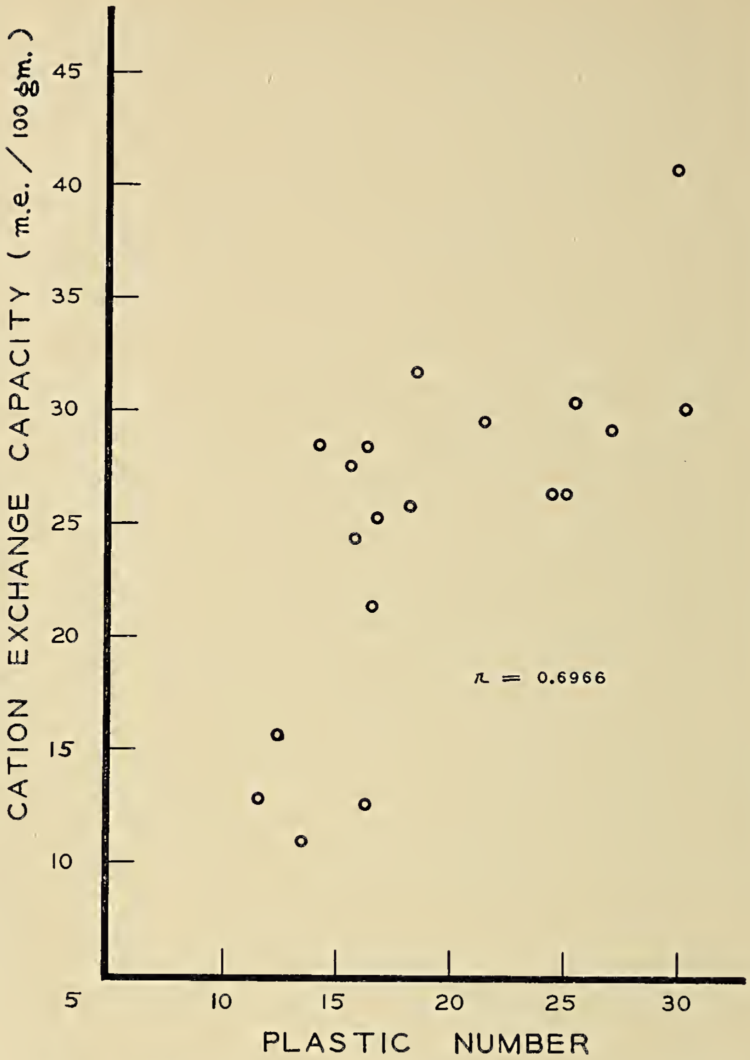

FIG. 1. The relation between cation exchange capacity in milliequivalents per 100 grams and plastic number of gray hydromorphic soils.

The data presented in Figure 2 show the relationship between per cent magnesium saturation and plastic number. There appears to be no real relationship between these factors. Likewise, there is no relationship between the ratio of exchangeable calcium to exchangeable magnesium and the plastic number. It is apparent that, since there is an observed relationship between per cent magnesium saturation and a dispersed condition of the soil, some other soil factor must play a major role in the development of the plastic properties of the clay.

The relationship between the organic matter content of the soil and the plastic number of the soil is shown in Figure 3. A correlation coefficient of .726 indicates a highly significant relationship between these two factors. Baver (1928) has shown that the plastic number of a soil increases as the organic matter content of the soil increases. The plasticity of these soils and their impermeability is much greater than those of other soils of corresponding clay and organic matter content.

In order to study the influence of organic matter on the plastic number, the organic matter was removed from a soil of the Kalihi family by treatment with hydrogen peroxide. Samples of the treated and untreated soil were placed in percolation tubes, and the percolation rate of distilled water through the samples was measured. Since there is an observed effect of per cent magnesium saturation on the physical condition, the level of magnesium was altered to determine the role of interrelationship between level of exchangeable magnesium and organic matter content on the impermeability of the soil. The data are presented in Figure 4. The removal of the organic matter increased the rate of percolation of water through the soil. Percolation of water through the sample possessing the organic matter progressed at a steady rate, while in the untreated soil the rate of percolation was fast at the beginning and then became progressively slower. The soil with low magnesium had the fastest percolation rate and the soil with the high magnesium level percolated in the same fashion as the untreated soil. The progressively slower percolation of the untreated sample and of the soil having a high magnesium level can be attributed to an increase in the dispersion of the colloidal system. Thus, the effect of both organic content and high magnesium level appears to be on the state of dispersion of the colloidal system, which can be increased by the degree of hydration.

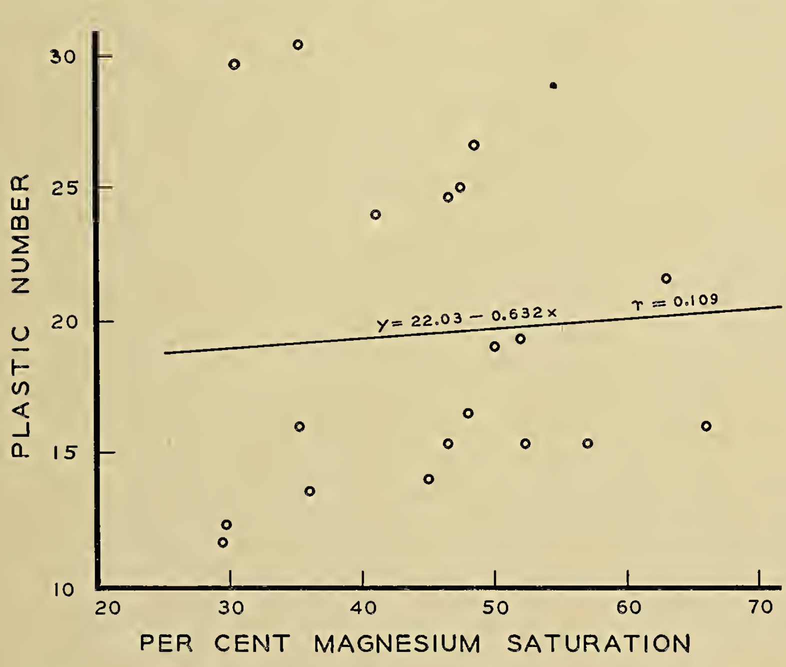

FIG. 2. The relationship between per cent magnesium saturation and plastic number of gray hydromorphic soils.

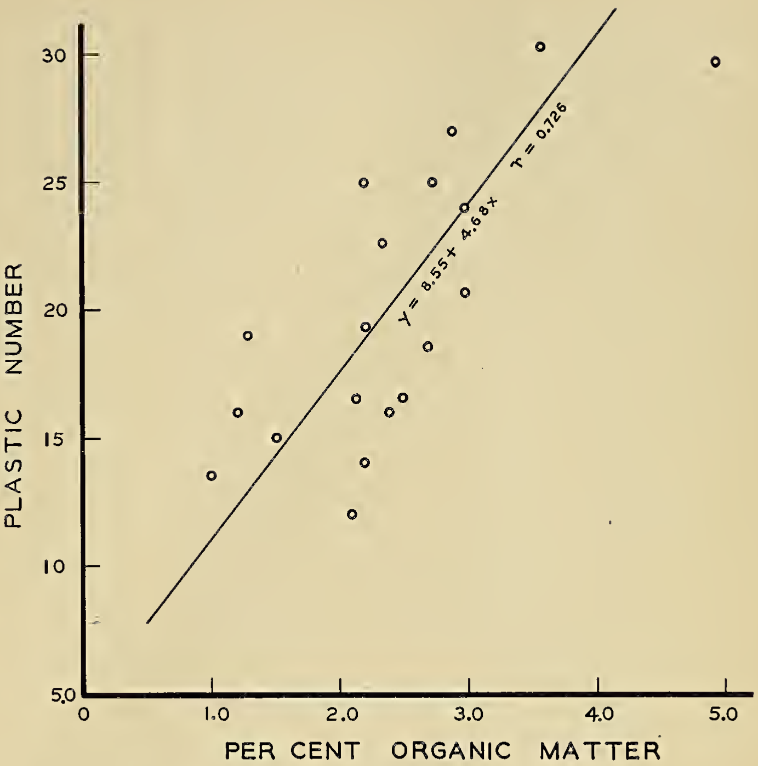

FIG. 3. The relationship between content of organic matter in the soil and plastic number of gray hydromorphic soils.

NATURE OF THE CLAY FRACTION

The chemical composition of the clay fraction of the gray hydromorphic soils is given in Table 2. There is a great similarity in the analysis of the clays of these soils. The silica content ranges from 38.1 to 41.2 per cent. Likewise, the aluminum oxide and iron oxide content of the clays of the three soils show very little variation. The low content of magnesium oxide in the crystal lattice rules out the possibility of magnesium substitution into lattice position being the cause of the plastic properties.

The type of clay minerals in the clay frac-

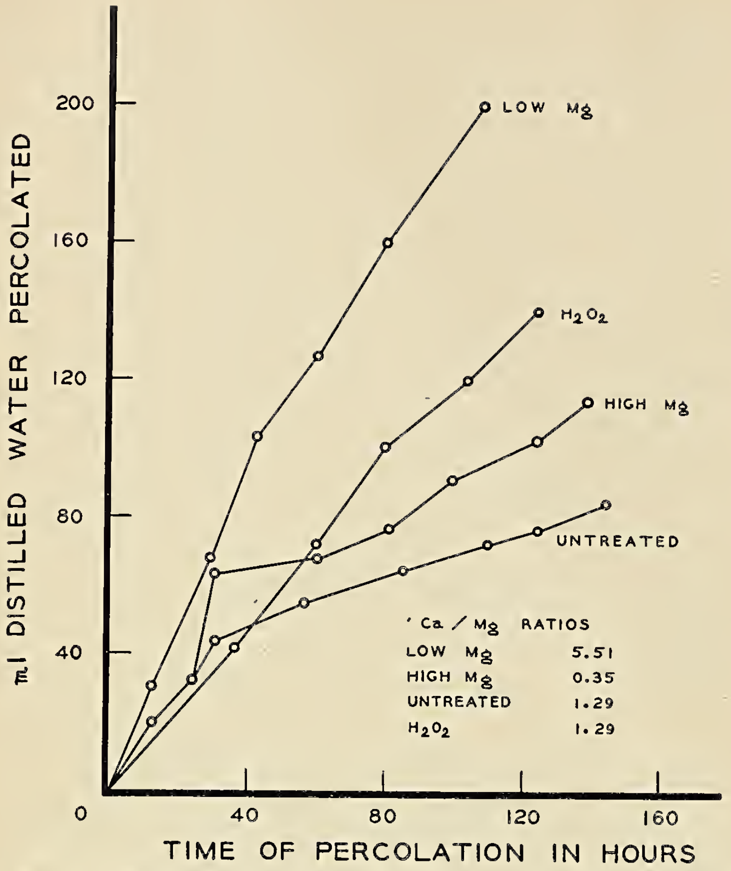

FIG. 4. The influences of organic matter content and exchangeable magnesium level on the rate of percolating water.

tion has been identified by differential thermal methods developed by Norton (1939). The thermal curves show that the dominant clay mineral in the Kalihi and Kaloko soils is of the montmorillonite type. The soils of the Honouliuli family have appreciable amounts of kaolinite. This would account for their lower cation exchange capacity. Matsusaka and Sherman (1950) found that the titration curves of the gray hydromorphic soils were similar to those of montmorillonite clays.

DISCUSSION

The results of this investigation have brought out the fact that there are several factors which influence the plastic properties of a soil. In general the type of clay, the organic matter content, and adsorbed cations are the most important. The exact details of the mechanism of magnesium-induced impermeability and plasticity are not known. It is suspected that hydration of the exchangeable magnesium ion is greater in the presence of certain humates and that this hydration results in a dispersion of the clay and organic matter. However, this dispersion is dependent upon a type of clay which perhaps must possess certain external and internal surface characteristics. The results of this study would indicate that only a montmorillonite clay can develop these plastic properties with these factors.

Humus influences the plastic properties of a magnesium-saturated clay by forming a complex or by establishing conditions which enable magnesium to become hydrated. Humate attached to the clay indirectly through the magnesium could widen the Helmholtz layer and cause an increase in the

TABLE 2

THE CHEMICAL COMPOSITION OF THE CLAY FRACTION OF TYPICAL SOILS OF THE GRAY HYDROMORPHIC GROUP

Soil family	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Honouliuli A Horizon	38.10	23.02	14.08	1.80	1.02	1.26
Kalihi A Horizon	41.07	25.12	11.80	1.52	0.50	0.99
Kalihi B Horizon	41.20	25.30	10.65	1.34	0.66	0.91
Kaloko A Horizon	39.81	25.20	14.70	1.85	0.44	0.80
Kaloko B Horizon	39.02	26.27	13.90	1.52	0.29	0.81

zeta potential. This would call for an inherent characteristic of magnesium alone or in combination with unique surface phenomena of the type of clay mineral in the soil.

Both the nature and amount of clay present in a soil play an important role in the plastic properties of the soil. The clay particles of the montmorillonite type of clay, which are plate-like structures, secure their plasticity from a small film between two particles which easily permits sliding along the axis of the longitudinal plane but requires a considerable force to pull the particles apart. An equilibrium of the component factors is set up in the clay fraction of the soil. The following are the component factors concerned:

(1) Clay. The clay has its maximum plastic properties only when the clay is completely dispersed and when water is present in sufficient quantities to fill the space between all of the particles to a uniform degree of thickness. The thickness will determine the viscosity of the plastic state. The ability of the clay to attract water will be determined by the type of clay and its charge (cation exchange capacity) which in turn will be determined by the characteristics of its crystal lattice and internal and external surface area.

(2) Exchangeable magnesium. The amount of exchangeable magnesium, which has the maximum observed potential dispersing power, is limited in its dispersing power by the amount of exchangeable calcium (a flocculating agent) present or by the amount of organic matter, which increases dispersive properties of magnesium by increasing its hydration.

(3) Organic matter. The amount and nature of the organic matter present in the soil have a maximum potential as a co-dispersing agent. The dispersing power of the magnesium is modified by the amount of organic matter present in the soil.

One of the observed characteristics of the gray hydromorphic soils is that exchangeable magnesium occupies 30 or more per cent of the cation exchange capacity. It has been observed that soils having this level of magnesium saturation always possess a high degree of plasticity when the calcium–magnesium ratio approaches equivalence. Since neither the per cent magnesium saturation nor the calcium–magnesium ratio is correlated with the plastic number of the soil, it is believed that neither of these factors is limiting. The per cent organic matter and the cation exchange capacity of the soil are correlated to a high degree to the plastic number. This would indicate that the two main factors involved in the development of the plastic properties are the amount of organic matter present and the inherent properties of the clay which is a montmorillonite type of clay mineral. The clay fraction of the gray hydromorphic soils does not possess an excessive electrical charge which can cause dispersion. The dispersion of the gray hydromorphic soils appears and disappears as the exchangeable magnesium, the organic matter, and the water hulls of hydration are added or removed.

SUMMARY

The gray hydromorphic soils of the Hawaiian Islands are capable of becoming dispersed and plastic when the per cent magnesium saturation exceeds 30 per cent in the presence of organic matter, providing the ratio of exchangeable calcium to exchangeable magnesium is approximately unity.

The calcium–magnesium ratio and the per cent magnesium saturation are not correlated with the plasticity of the soil. The content of organic matter and the cation exchange capacity of the soil are significantly related to the development of the plastic properties.

A decrease in the amount of exchangeable magnesium present or the removal of the organic matter from these soils increases the rate of percolation of water through these soils, which indicates a decrease in its degree of dispersion. Since all soils do not respond

in this manner, the inherent properties of the clay must be responsible for these attributes. The clay has been identified as a montmorillonite type by differential thermal methods.

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A New Variety of *Pandanus* and a New Species of *Fimbristylis* from the Central Pacific Islands. Pacific Plant Studies No. 11[1]

HAROLD ST. JOHN[2]

INTRODUCTION

SINCE 1945 THE WRITER has made three expeditions to the small islands of the Central Pacific. The first, in 1945, was backed by the University of Hawaii; the second, in 1946, by the University of Hawaii and the Pacific Science Board; the third, in 1949, by the Donaldson Expedition of the Atomic Energy Commission. On these trips a number of novelties were collected which are worth putting on record.

PANDANACEAE

Pandanus odoratissimus L. f. var. ***novo-caledonicus*** (Martelli) comb. nov. *P. tectorius* Parkinson var. *novo-caledonicus* Martelli, Webbia 4(2): 412–413, 1914; 4(1): 34, table 12, figs. 1–2, 1913.

Marshall Islands: Eniwetok Atoll, Runit Islet, s. e. islet of, in thicket on coral sand, 3 m. alt., tree 8 m. × 3 dm., Aug. 15, 1949, *St. John 23,840.*

Pandanus odoratissimus L. f. var. ***novo-guineensis*** (Martelli), St. John, Pacific Sci. 5(3): 280, 1951.

Marshall Islands: Eniwetok Atoll, Rujoru Islet, in scrub forest on coral sand, 4 m. alt., tree 8 m. × 2 dm., Aug. 13, 1949, *St. John 23, 811;* Runit, s.e. isthmus, on sand with low *Scaevola frutescens,* 2 m. alt., only one tree 7m.×2 dm., Aug. 15, 1949, *St. John 23,842;* also on Aniyaanii Islet, *St. John 23,715;* and Rigili Islet, *St. John 23,753.*

CYPERACEAE

Fimbristylis atollensis St. John sp. nov. § *Dichelostylis.* Figs. 1, 2.

DESCRIPTIO TYPI: Perennis caespitosa, culmis 25–38 cm. altis erectis striatis angulosis compressis laevibus glabris 0.3–1.2 mm. latis, foliis omnibus basilaribus pluribus congregatis adscendentibus divergentibusve, eis plantarum maturarum ⅓ ad ½ longis quam culmas, foliis 4–14 cm. longis 0.6–1.2 mm. latis pallide viridibus coriaceis rigidibus, pagina superiora infra media late canaliculata supra minus canaliculata et ad apicem plana, marginibus minute remoteque adpresse apiculato-serrulata, apice irregulariter obliqueque truncato et grande apiculato-serrulato, inflorescentiis decompositis, bracteis tribus inferioribus glabris laminiferis 5–15 mm. longis quam spicas sessiles longioribus, radiis 5–8 valde inaequalibus 0.2–4.0 cm. longis laevibus compressis in utrinque latere valde 4–5-angulosis circa 45° adscendentibus, brevioris simplicibus in apice 1, 2, vel 3 spiculis sessilibus gerentibus, longioribus compositis in apice plerumque 3 spiculis gerentibus mediale sessile, spiculis lateralibus sessilibus subsessilibus vel pedunculo ad 4 mm. longo affixis etiam 2–4 radiolis 3–18 mm. longis gerentibus eis cum 3 (vel 2) spiculis sessilibus terminalibus, bracteolis pluribus stramineis exteriore laminifera sed quam

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[1] This is the eleventh in a series of papers designed to present descriptions, revisions, and records of Pacific island plants. The preceding papers were published as: *Bernice P. Bishop Mus., Occas. Papers* 17(7), 1942; 17(13), 1943; 18(5), 1945; *Amer. Fern Jour.* 35: 87–89, 1945; *Torrey Bot. Club, Bul.* 73: 588, 1946; *Pacific Sci.* 1(2): 116, 1947; 2(2): 96–113, 1948; 2(4): 272–273, 1948; 5(3): 279–286, 1951; *Webbia* 8: 225–228, fig. 1, 1951.

[2] Chairman, Department of Botany, University of Hawaii. Manuscript received June 1, 1950.

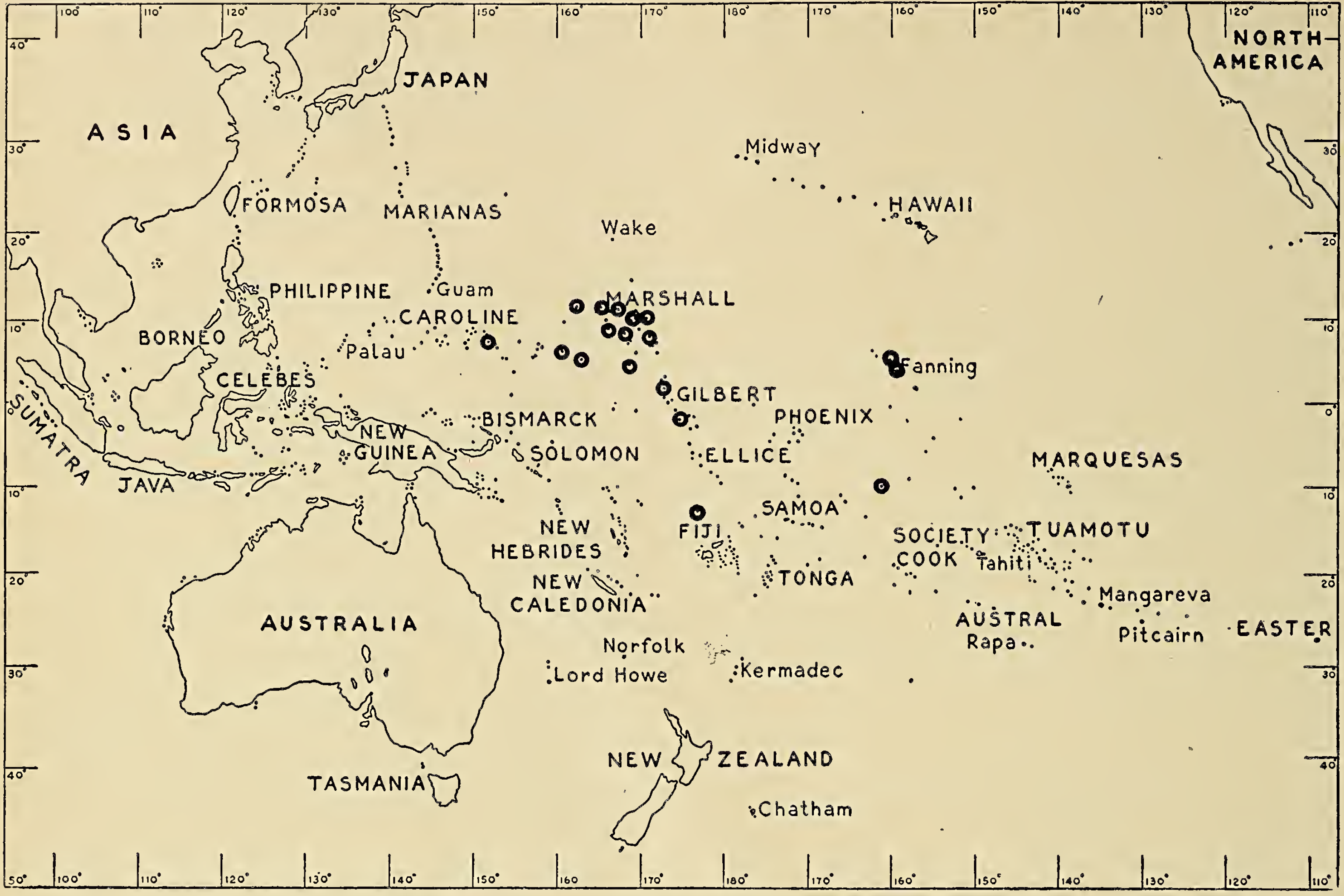

FIG. 1. *Fimbristylis atollensis* St. John, circles on known localities.

spiculam breviore, spiculis 3–7 mm. longis 1.3–1.8 mm. latis ovoideis vel lanceo-ovoideis acutis, rhachillis cum alis transversalibus 0.5 mm. longis brunneis ellipticibus margine scarioso, cicatricibus lunatis, glumis spiralibus imbricatis 1.5–1.7 mm. longis rhomboideo-suborbicularibus glabris lucidis brunneis marginibus superioribus protrudentibus albis hyalineis, carina crassa paene ad apicem prominente, nervis lateralibus 2–4 uno latere approximatis longituditer parallis brevibus inconspicuis, staminibus 2, filamentis 1.2 mm. longis ligulatis hyalineis, antheris 0.5–0.6 mm. longis oblongo-linearibus subacutis, stylo glabro 0.5–0.8 mm. longo in basi dilatato conico, stigmatibus 2 divergentibus 0.7–0.9 mm. longis filiformibus, achaeneis 0.5–0.6 mm. longis turbinatis crasse plano-convexis laevibus sine striatis obscure fuscis basi truncata apice lato subtruncato, latere convexo rotundato.

DESCRIPTION OF ALL SPECIMENS: Densely caespitose perennial; stems 25–60 cm. tall, erect, angular striate, compressed and flattened throughout, the surface smooth and glabrous, 0.3–1.3 mm. wide; leaves all basal, several, crowded, ascending or later diverging, those of mature clumps ¼–⅔ the length of the culms, 2–38 cm. long, 0.5–2.8 mm. wide, pale green, coriaceous, rigid, the upper side wide-channeled below the middle, above the middle more shallowly so and towards the tip flat, the margin minutely and remotely apiculate appressed serrulate, the apex irregularly obliquely truncate and coarsely apiculate serrulate; inflorescence decompound; the 3 or 4 lower bracts glabrous blade-bearing 5–30 mm. long, exceeding the 1–3 central sessile spikes; rays 3–8 in number, very unequal 0.2–4.0 cm. long, smooth, flattened with 4–5 strong angles on a side, ascending at about 45° to the axis, the shorter ones simple, bearing at their tips 1, 2, or 3 sessile spikelets; the longer rays compound, bearing at their apices mostly 3 spikelets, the central one sessile, the lateral ones sessile, subsessile,

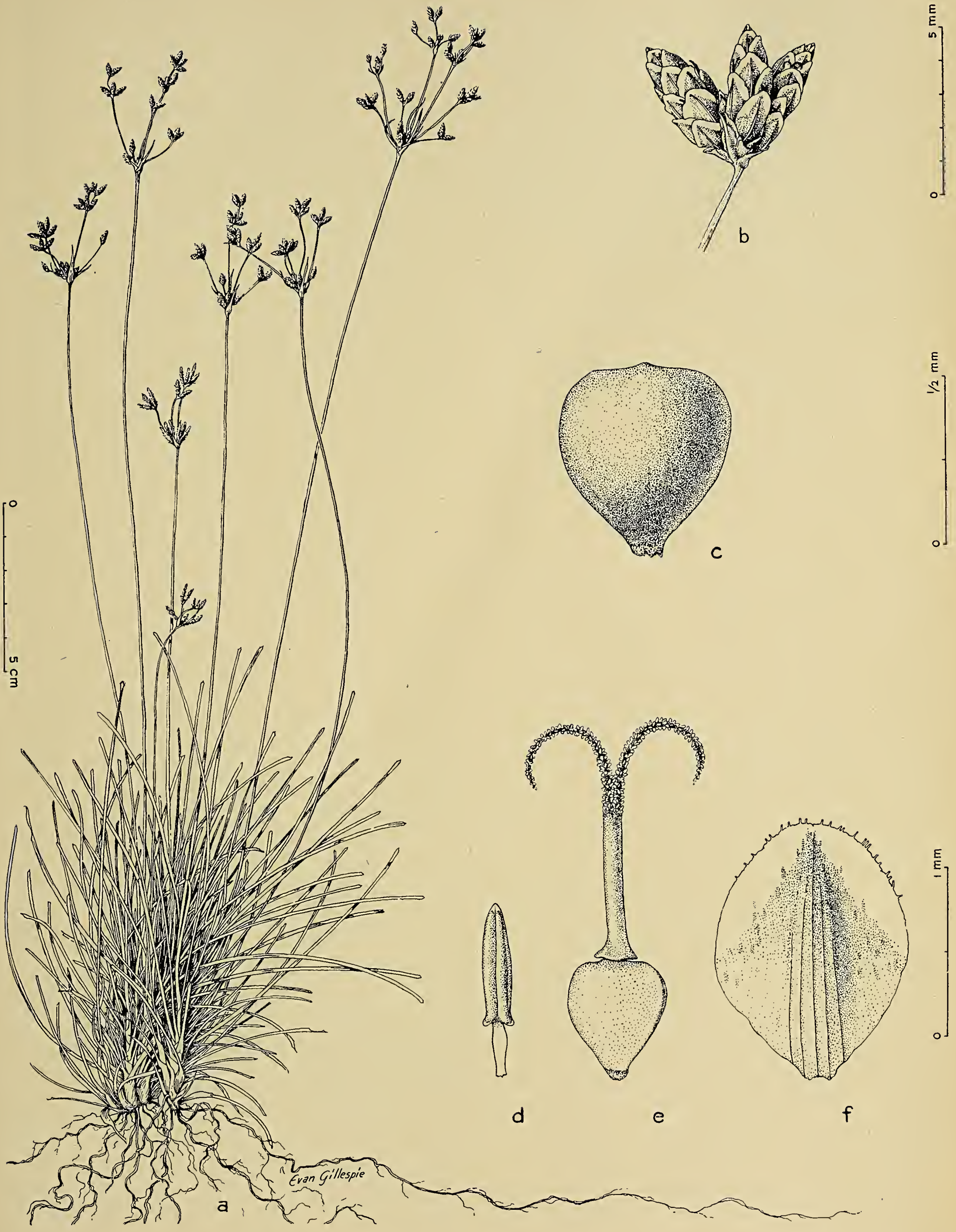

FIG. 2. *Fimbristylis atollensis* (from the type, St. John 23,721): *a*, Habit, ×½; *b*, spikelets, ×5; *c*, achene, ×50; *d*, stamen, ×25; *e*, pistil, ×25; *f*, scale, ×25.

or with peduncles up to 4 mm. in length, also bearing 2–4 raylets 3–18 mm. long which terminate in 3 (or 2) sessile spikelets; bractlets several, stramineous, the outer blade-bearing but shorter than the spikelet; spikelets 3–7 mm. long, 1.3–1.8 mm. wide, ovoid or lance-ovoid, acute, in age or post maturity to 10 mm. long, cylindric; rhachilla with transverse wings which are 0.5 mm. long, brown, elliptic, scarious margined; fruit scar lunate; scales spirally imbricate, 1.2–1.7 mm. long, rhomboid-suborbicular, glabrous, shining, brown except for the white hyaline upper exposed lateral margins, the midrib thickened, prominent almost to the tip, lateral veins 2–4 on a side closely parallel to the midrib, short, obscure; stamens 2, the filaments 1.2 mm. long, ligulate, hyaline; anthers 0.5–0.6 mm. long, oblong-linear, subacute; style glabrous 0.5–0.8 mm. long, dilated and conic at base; stigmas 2, diverging, 0.7–0.9 mm. long, filiform; achene 0.5–0.6 mm. long, turbinate, thick plano-convex, without ridges, lines, or mottlings, but dull fuscous and in strong light with a few shining points from lenticular epidermal cells, but the general surface dull, the base truncate, the apex broad, subtruncate, the convex side full and rounded. (Very rarely there is a flower with 3 stigmas and it produces a trigonous achene sharply angled on the distal side.)

TYPE: Marshall Islands: Eniwetok Atoll, Aniyaanii Islet, 3 m. alt., in coral sand, tufts 1 dm. across, Aug. 8, 1949, Atomic Energy Commission, Donaldson Expedition, *Harold St. John 23,721* (Bishop Museum).

Specimens Examined

LINE ISLANDS

Fanning Island: generally distributed in open places, el. —7 m., July 31, 1922, *S. C. Ball 8;* on waste land around copra station, July 31, 1924, *E. Christophersen 17;* Dec., 1924, *G. P. Wilder 3.*

Washington Island: in moist soil, Aug. 13, 1924, *H. F. Bergman 77.*

Rakahanga Island: sandy soil, open ground, dry, sea level, Mar. 10, 1927, *G. P. Wilder 536.*

MARSHALL ISLANDS

Eniwetok Atoll: Bogon Islet, tufts on coral sand, 2 m. alt., Aug. 11, 1949, *H. St. John 23,771;* Engebi (as Engabi) Island, Aug. 21, 1944, *E. H. Bryan Jr.;* Runit Islet, rare, tufts on coral sand, 4 m. alt., Aug. 15, 1949, *H. St. John 23,849.* Also observed in 1949 by St. John on Aomon, Aniyaanii, Japtan, and Eniwetok Islets.

Bikini Atoll: Bikini Island, Crossroads Expedition, Mar. 30, 1946, *W. R. Taylor 46-1098.*

Rongelap Atoll: Rongelap Island, Crossroads Expedition, July 21, 1946, *W. R. Taylor 46-1470;* Eniwetok Island, June 16, 1946, *W. R. Taylor 46-1362.*

Likiep Atoll: Likiep Island, tufted, in coral gravel, common, Aug. 28, 1946, *H. St. John & R. S. Cowan 21,776,* vernacular name "pĕrĕrlĭtchman."

Ailuk Atoll: Ailuk Island, in coral sand, common, Aug. 30, 1946, *H. St. John & R. S. Cowan 21,833,* vernacular name "dilĭtchman"; Marme Island (south of Marappu Island), tufts on open sand, Aug. 31, 1946, *H. St. John & R. S. Cowan 21,868.*

Mejit Island: in wet *Cyrtosperma* pit, Sept. 3, 1946, *H. St. John & R. S. Cowan 21,940,* vernacular name "berelĭtchman." Doubtless the collection, "bei dem Händlerplatz, Mejijt, (*K. Gibbon* n. 1076)," listed by Kükenthal (in Engler's Bot. Jahrb. 59: 5–6, 1924) as *F. glomerata* f. *spathacea,* will prove to be of this new species; also the record from Jaluit (*Finsch* n. 4); and perhaps that from Ponape (*Ledermann* n. 13,979).

Wotje Atoll: Ormed Island, abundant throughout island, Sept. 4, 1946, *H. St. John & R. S. Cowan 22,039,* vernacular name "drelĭtchman."

Aur Atoll: Tabal Island, in open sand by shore or in open woods nearby, Dec. 17, 1945, *H. St. John 21,399,* vernacular name "wujoĭt" [=a grass].

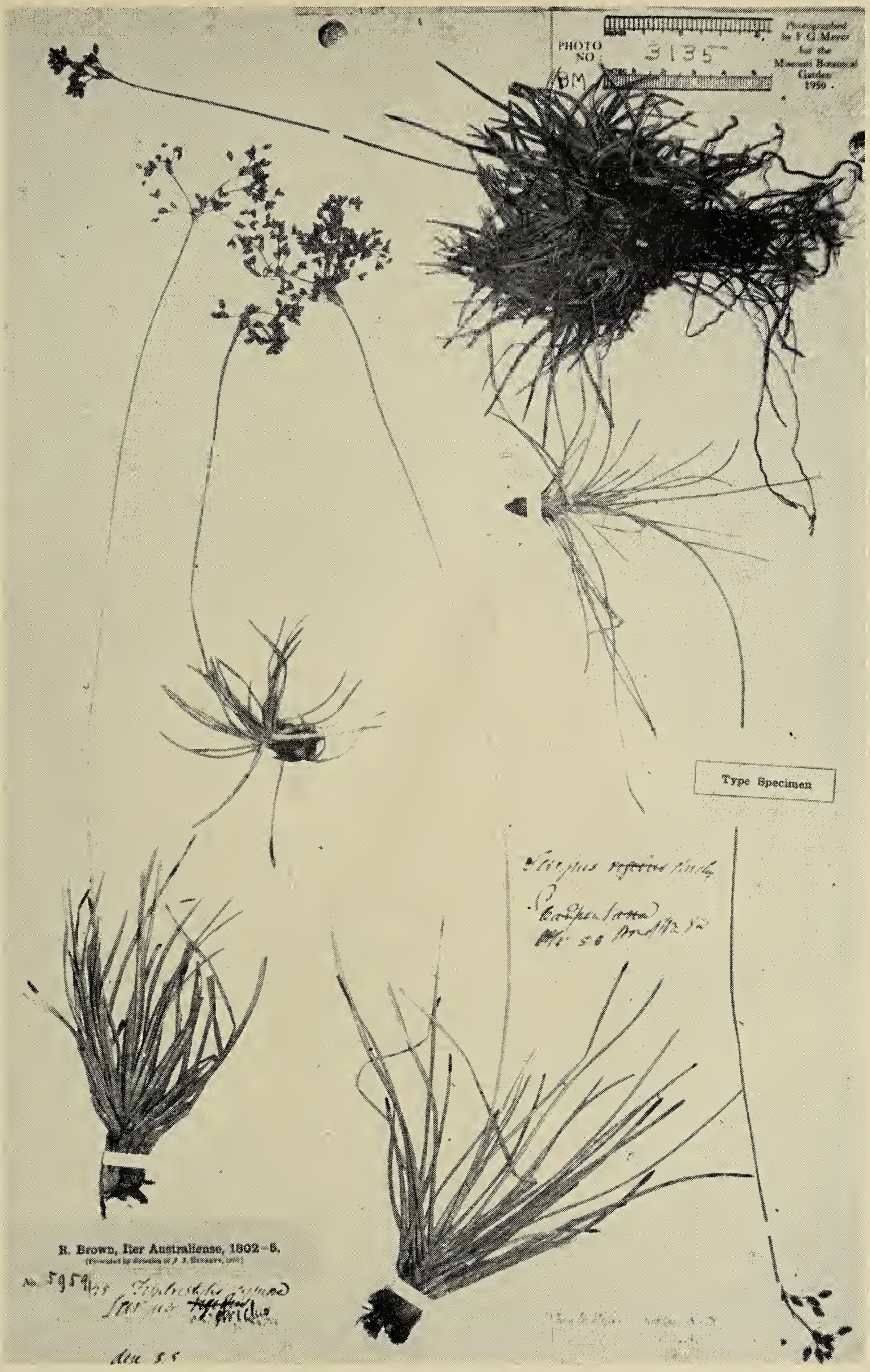
PHOTO NO 3135
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Photographed by F. G. Meyer for the Missouri Botanical Garden 1959
Type Specimen
R. Brown, Iter Australiense, 1802–5.
No. 5959

FIG. 3. *Fimbristylis cymosa* R. Br., type (Brit. Mus.), Iter Australiense 1802–5, Carpentaria, R. Brown 5,959.

Kwajalein Atoll: Ebeye Island, near s. end in garden, spontaneous, Aug. 3, 1944, *E. H. Bryan Jr.*

Namu Atoll: Namu Island, Aug. 16, 1946, *H. St. John & R. S. Cowan 21,607*, vernacular name "merelĭjiman."

Ebon Atoll: Ebon Island, Chittakain, tufted in coral sand, abundant, Sept. 11, 1946, *H. St. John & R. S. Cowan 22,182*, vernacular name "berelĭtchman."

GILBERT ISLANDS:

Tarawa Atoll, Oct. 1944, Sgt. *C. E. R. Cameron.*

Tabite Ue A Island [Tapeteuea Atoll]: in clumps, abundant lagoon side, perfumed roots used to perfume grass skirts, Nov. 5, 1948, *K. Luomala 11*, vernacular name "te uteute te mane" [=the male grass].

Rotuma Island: Huo, Oinafa District, alt. 10 ft., by shore, tufted, in crevices of sea cliffs and basalt ledges, July 26, 1938, *H. St. John 19,282*, vernacular name "pupu"; Haua Meamea Island, sea cliff, tufted, in crevices of basalt, alt. 15 ft., Aug. 1, 1938, *H. St. John 19,370.*

CAROLINE ISLANDS:

Kusaie Island, Mot, herb, flower brown, grows on shady soil, Jan. 26, 1936, *M. Takamatsu 448.*

Pingelap Island: in woods by lagoon beach, Dec. 27, 1945, *H. St. John 21,491*, vernacular name "rosakai."

Truk Islands: Truk, sandy soil near seashore, CIMA Expedition, Sept. 24, 1947, *C. C. Y. Wong 129*, vernacular name "enenikkö."

This plant is common on the atolls of the Central Pacific and has often been collected. It has customarily been identified as *F. cymosa* R. Br., but that species, described from the Gulf of Carpentaria and Prince of Wales Islands, has the spikelets single or on longer inflorescences with less than half of them paired; scales ovate, the 3 lateral veins on each side strong; stigmas 3, and 0.5 mm. long; and the achenes oblong-obovoid, trigonous but somewhat plano-convex, whitish brown, transversely rugulose. It is a member of the section *Trichelostylis*, and the series *Glomeratae*. On the other hand, *F. atollensis* has the spikelets 3 (or 2) at a node, 1.3–1.8 mm. wide; scales rhomboid-suborbicular, the lateral veins 2–4 on a side, short, obscure, closely parallel to the midrib; stigmas 2 and 0.7–0.9 mm. long; and the achenes turbinate, thick plano-convex, dull fuscous, without ridges, lines, or mottlings. This new species falls into quite a different position in the genus, in the section *Dichelostylis* and into series B** (Clarke, Kew Bul. 106, 1908). The several species in this series are strikingly different, but it seems that the closest is *F. macrostachya* Boeck. of Port Darwin, Nothern Territory, Australia. This differs in having the leaves plane above; scales rigid, strongly mucronate, many striate, stramineous; ovary long stipitate; and the style densely ciliate. On the other hand, *F. atollensis* has the leaves channeled above, the scales brown, scarious, broadly obtuse, only the midrib prominent; ovary sessile, and the style glabrous.

The type of *F. cymosa* R. Br. was recently critically studied by the writer at the British Museum of Natural History in London. A photograph of the type sheet is included (Fig. 3).

Notes on the Mosquitoes of Nissan Island, Territory of New Guinea[1]

MARSHALL LAIRD[2]

NISSAN ISLAND, also known as Green Island, Sir Charles Hardy Island, or Los Caimanes, lies approximately halfway between the Solomon Islands and the Bismarck Archipelago. Some 50 miles east of southern New Ireland (Bismarck Archipelago) and 40 miles northwest of Buka (northern Solomons), it is in line with the main chain of the Solomons. The island is an elevated atoll, the seaward cliffs of the eastern side, in places upwards of 100 feet in height, owing their formation to gentle tilting associated with the elevation (Davis, 1928). An area of about 7 miles by 4 miles is enclosed by the atoll rim, which is never more than a mile, and often only a few hundred yards, in width. Before its military occupation Nissan was densely bushed, with the exception of two coconut plantations and a few native clearings. Some earlier accounts have overestimated the size of the island. Thus Schmiele (1891) speaks of it as being 15 miles in diameter with a rim 2 or 3 miles wide, and Hartert (1926) gives its dimensions as "about 27 km. long and 21 wide."

Nissan was held by the Japanese from 1942 to February, 1944, when an Allied force which included the Third New Zealand Division recaptured it. Two airstrips were laid down, and the island was used as an Allied air base until the middle of 1945. The local incidence of *Anopheles* and malaria being high, strict mosquito control was maintained throughout the military area during this period. Thus the initial malaria rate was low, only 46 cases being recorded among 6,922 New Zealand troops during the 3-month period from the landing until the departure of the Division in May, 1944. During the remainder of the Allied occupation, cases of primary malaria were infrequent and were usually traceable to infection outside the controlled area.

When Nissan was abandoned as an operational base, malaria control had been in force for almost a year and a half. The material discussed below was collected during a 10-day visit to the island in September, 1945. It was of particular interest to note how rapidly and completely *Anopheles* had reoccupied the abandoned base in the 2 months which had elapsed since the cessation of mosquito control activities.

Three species of mosquitoes have previously been recorded from Nissan: *Anopheles* (*Myzomyia*) *farauti* Laveran, recorded by Perry (1945); *Tripteroides* (*Tripteroides*) *nissanensis* Lee, described from material collected by L. J. Dumbleton; and *Aëdes* (*Finlaya*) *kochi* (Dönitz), recorded by Marks (1947) from material collected by L. J. Dumbleton.

T. nissanensis was not recorded in the present survey. The other two species and the following four additional ones were collected: *Aëdes* (*Stegomyia*) *quasiscutellaris* Farner and Bohart, *Aëdes* (*Aëdes*) *carmenti* Edwards, *Armigeres breinli* (Taylor), and *Culex* (*Culex*) *annulirostris* Skuse.

THE BIOLOGY OF MOSQUITO LARVAL HABITATS

The vegetation of ground pools on the overgrown Tangalan plantation closely resembled that of similar pools in New Britain (Laird, 1947) and the Solomons. *Paspalum conjugatum* Berg., *Echinochloa colona* O. Kuntze, and *Eleusine indica* Gaerter were the usual marginal grasses. As at Jacquinot Bay, New Britain, clumps of *Pennisetum macrostachyum* (Brongn.), *Clitoria* sp. (Papilionaceae), and *Cucumis* sp. (Cucurbitaceae) were also commonly present. Algal mats were composed mainly of the green algae *Spirogyra* and *Hormidium* or the blue-greens *Oscillatoria*, *Anabaena*, and a member of the Chroococcaceae.

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[1] Royal New Zealand Air Force Entomological Bulletin No. 8. Authorized by Chief of Air Staff. Manuscript received September 4, 1951.

[2] Entomologist, Medical Branch, Royal New Zealand Air Force.

Hemipterans of the families Notonectidae, Gerridae, and Veliidae, a small dytiscid beetle of the genus *Bidessus*, nymphs of Odonata, and developmental stages of Chironomidae (Diptera) comprised the usual macrofauna associated with mosquitoes in long-established ground pools. There was insufficient time available for studying the significance of any of these arthropods as predators of developing mosquitoes. Webs of spiders belonging to the genera *Epeira* and *Carepalxis* often spanned portions of ground pools and such artificial larval habitats as oil drums. On several occasions remains of adult *Anopheles farauti* and *Culex annulirostris* were found in these webs.

NOTES ON THE BIONOMICS OF THE MOSQUITOES COLLECTED

Anopheles farauti Laveran, 1902, Soc. de Biol., Compt. Rend. 54: 908.

At the time of the survey there were 18 ground pools of a semipermanent nature in the abandoned RNZAF area in Tangalan plantation. Sixteen of these pools held developmental stages of *A. farauti*. Although many of them were exposed to direct sunlight and contained predaceous insects, shade and shelter were afforded the anophelines by marginal and emergent vegetation, floating masses of green and blue-green algae, and surface debris. The other two pools were without vegetation other than felted, bottom-dwelling algae. Although numerous other arthropods were present in these, mosquitoes were absent. The presence of predators together with the lack of sheltering vegetation probably explained the absence of anophelines from these two pools.

Larvae of *Culex annulirostris* were always associated with those of *A. farauti* in the ground pools examined. Estimates of the hydrogen-ion content of the water of these larval habitats made with nitrazine paper ranged from *p*H 5.5 to *p*H 7.0 and averaged *p*H 6.5. During the daytime the water temperature averaged about 33°C. and once was recorded as 41°C. in an exposed situation. In this last case, all the larvae of both *C. annulirostris* and *A. farauti* present were sheltering in the shade afforded by floating coconut husks and an oil drum half-submerged in the water. The average larval population of *A. farauti* per square foot of water surface (50 counts) was 75, early instars outnumbering fully developed larvae by about five to one.

On one occasion numerous anopheline larvae were found in association with those of *C. annulirostris* and *Aëdes quasiscutellaris* in a 44-gallon drum half-filled with water, shaded by the eaves of an abandoned hut. The water was cloudy and its hydrogen-ion content was *p*H 6.0. Many larvae and pupae of Chironomidae were associated with the mosquitoes. *A. farauti* was recorded from only one other artificial larval habitat on Nissan, when seven fully developed larvae and one pupa were found, together with 25 larvae and pupae of *A. quasiscutellaris*, in a tin can shaded by tall grasses and containing 300 cc. of rain water.

Numerous adult females of *A. farauti* were captured at the camp each evening. In addition, many specimens of both sexes were taken by sweeping the marginal grasses around larval habitats during the daytime with a hand net.

Aëdes (Finlaya) kochi (Dönitz, 1901), Insekten-Börse 18: 38.

Developmental stages were found in water held in the leaf axils of most of the taro plants (*Colocasia* sp.) examined. This water was always clear, the hydrogen-ion content ranging from *p*H 6.0 to *p*H 7.0, and the water temperature averaging 29°C. (some 2° less than the shade air temperature) during the daytime. The average population of *A. kochi* (50 counts) was five larvae and pupae per cubic centimetre of water. The largest number recorded in one leaf axil was 136 (81 early instar larvae, 43 late instars, and 12 pupae) in 15 cc. of water. Developmental stages of Chironomidae were commonly found in association with those of *A. kochi.* Large numbers of small ants were once noticed swarming over the leaf and stem surfaces down to the edge of a small pocket of water (about 2 cc.) in a taro leaf axil. The water held two early instar and three late instar larvae of *A. kochi*, which were promptly seized upon by the ants when the water was drained away by means of a knife cut.

A. kochi females were abundant at the camp during the evenings, and featured prominently in biting collections made from dusk until about 11:00 P.M.

Aëdes (Stegomyia) quasiscutellaris Farner and Bohart, 1944, Biol. Soc. Wash., Proc. 57: 120.

Like other members of the *scutellaris* group, *Aëdes quasiscutellaris* breeds readily in domestic situations. Developmental stages were collected from a variety of habitats, for the most part domestic in nature. These included 44-gallon drums, an old water tower, truck tyres lying flat on the ground, tin cans, coconut husks, and tree holes. In drums and tanks they were often associated with *Culex annulirostris*, and once with *Anopheles farauti* as well. Many larvae of *A. quasiscutellaris* and *C. annulirostris* were found in a flour drum full of water in the dark interior of a shed. *A. quasiscutellaris* was never found in association with other species of mosquitoes in such larval habitats as water held in truck tyres, coconut husks, and tree holes.

The water temperature in larval habitats of *A. quasiscutellaris* was generally some two or three degrees Centigrade above that of the shade air temperature at midday. In one such habitat, a 44-gallon drum standing in an exposed situation at the edge of one of the airstrips, the midday water temperature was found to be 36°C. The hydrogen-ion content of water holding developmental stages of this species ranged from *p*H 5.5 to *p*H 6.5.

Chironomidae were constantly associated with *A. quasiscutellaris* throughout its range of larval habitats, and adults and larvae of dytiscid beetles (*Bidessus* sp.) were sometimes plentiful. The presence of the latter insects did not appear to have any appreciable effect on the numbers of *Aëdes* present.

Adults of *A. quasiscutellaris* were not troublesome during the evenings, but bit constantly in shady places near larval habitats during the daytime.

Aëdes (Aëdes) carmenti Edwards, 1924, Bul. Ent. Res. 14: 388.

No breeding places were ever discovered. Adult females were common and bit readily in shady jungle during the daytime. A few were captured in a lighted room in the early evening.

Armigeres breinli (Taylor, 1914), Roy. Ent. Soc., London, Trans. 1914: 186 (*Neosquamomyia*).

Developmental stages were commonly found in coconut husks which had been pierced for drinking purposes. These husks had a small hole in one place only, and held water of a yellowish colour heavily charged with decomposing copra. They were usually shaded from direct sunlight by grasses, and the water within them attained an average midday temperature of 28°C., some 3° less than the prevailing shade air temperature. Water emptied from these husks frequently held a wriggling mass of larvae and pupae of *A. breinli.* In one case 363 early instar larvae, 119 late instars, and 41 pupae were counted in 250 cc. of water from a single husk. No other mosquitoes were associated with *A. breinli* in any of the larval habitats examined, but hover-fly larvae (Syrphidae) were sometimes present.

The species was troublesome in the shade of abandoned buildings and at the jungle's edge throughout the day, especially so in the late afternoon. On one occasion numerous *A. breinli* together with a few *Aëdes quasiscutellaris* were noticed biting two domestic cats resting in the shade of a wall at midday.

Culex (Culex) annulirostris Skuse, 1889, Linn. Soc. N. S. Wales, Proc. 13: 1737.

Collections were made from 26 larval habitats, 16 of these being the ground pools utilized by *Anopheles farauti*. *C. annulirostris* was recorded from water in 44-gallon drums four times: once alone, twice in association with developmental stages of *Aëdes quasiscutellaris*, and once with both this species and *Anopheles farauti*. Larvae were also found with those of *A. quasiscutellaris* in the flour drum indoors previously mentioned. The other larval habitats noted were truck tyres (twice), an exposed wheelbarrow holding a few inches of rain water (the midday temperature of which was recorded as 40°C.), a pool on the steel tray of an abandoned truck, and water held in the folds of a self-sealing rubber petrol tank. In the latter cases larval Chironomidae were the only other arthropods present.

C. annulirostris was the most abundant and most troublesome mosquito during the earlier part of the evening. Adults of both sexes were attracted in large numbers to lighted huts. They were also collected during the day, together with *Anopheles farauti*, by sweeping the vegetation bordering ground pools.

DISTRIBUTION

Four of the seven mosquito species now listed from Nissan are common to the Solomon Islands and the Bismarck Archipelago: *Anopheles farauti* occurs throughout both island chains (Lee and Woodhill, 1944; Belkin *et al.*, 1945; Laird, 1946*a*); *Aëdes carmenti* is common to the Solomons (Edwards, 1924; Paine and Edwards, 1929), New Ireland (Edwards, 1925), and New Britain (Laird, 1946); *Armigeres breinli* is known from the Solomons (Paine and Edwards, 1929) and New Britain (Laird, 1946); and *Culex annulirostris* occurs throughout the South Pacific. *C. annulirostris* is widespread in the Solomons (Edwards, 1924) and has been collected in New Britain (Laird, 1946).

Of the other three species, one is indigenous but closely related to a species found in both island groups, one has not been recorded with certainty from the Solomons, and one does not occur in the Bismarck Archipelago. Lee (1945) states that *Tripteroides nissanensis* is closely allied to *T. quasiornata* (Taylor), which occurs in the Solomons (Belkin, 1945) and New Britain (Hill, 1925; Laird, 1946). *Aëdes quasiscutellaris* occurs throughout the Solomons (Farner and Bohart, 1945), but in the Bismarck Archipelago its place is taken by *Aëdes scutellaris* (Walker) (Stone and Farner, 1945; Stone, 1947). *Aëdes kochi* is a common mosquito in the Bismarcks where it is known from New Ireland (Taylor, 1934) and New Britain (Hill, 1925; Laird, 1946). There is no certain record of this species from the Solomons, and Marks (1947) states that Nissan is probably near its eastern limit.

MEDICAL SIGNIFICANCE

Malaria: *Anopheles farauti* is the principal vector of *Plasmodium* in the Solomons (Perry, 1945) and an important vector in the Bismarck Archipelago (Heydon, in Lee and Woodhill, 1944).

Filariasis: *Anopheles farauti* is claimed to be the most important vector of *Wuchereria bancrofti* in the Solomons (Anon., 1944). *Aëdes kochi* (Marks, 1947) and *Culex annulirostris* (Anon., 1944) may also act as vectors for this parasite.

SUMMARY AND CONCLUSIONS

The mosquito control measures practised on Nissan Island throughout the period of

Allied military occupation included weekly larvicidal treatment of all ground pools within the camp areas. Over the latter (and major) part of the period, 5 per cent DDT in Diesel oil was used for this purpose. From the fact that the pools examined in the present survey already supported thriving populations of various arthropods two months after the cessation of mosquito control activities, it is apparent that the residual effect of this treatment was short-lived. This was probably largely due to tropical downpours flushing away the DDT-Diesel oil emulsion from the pools. The rapidity with which *Anopheles* may reoccupy an area from which it has been temporarily excluded by control measures is well illustrated by the fact that all suitable larval habitats for *Anopheles farauti* in the old camp areas held heavy populations of this species when the survey was conducted. It may be that the presence of such large numbers of anopheline larvae (average: 75 per square foot of water surface) represented a temporary population peak made possible by the fact that the normal biological balance between *A. farauti* and its natural enemies had not yet been restored, because of the longer time required for the rebuilding of sufficiently heavy populations of such predators as Zygoptera, Coleoptera, and Gerridae to keep breeding of the anopheline in check.

The following mosquitoes are recorded from Nissan Island for the first time: *Aëdes* (*Stegomyia*) *quasiscutellaris* Farner and Bohart, *Aëdes* (*Aëdes*) *carmenti* Edwards, *Armigeres breinli* (Taylor), and *Culex* (*Culex*) *annulirostris* Skuse.

Of the seven species of mosquitoes now known from Nissan, four are common to the Solomon Islands and the Bismarck Archipelago, one is indigenous, and two are otherwise restricted to the Solomons and the Bismarck Archipelago respectively.

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The *Aedes* Mosquitoes of the Philippine Islands

II. Subgenera *Skusea, Christophersiomyia, Geoskusea, Rhinoskusea,* and *Stegomyia* (Diptera, Culicidae)[1]

KENNETH L. KNIGHT AND WILLIAM B. HULL[2]

INTRODUCTION

THIS IS THE SECOND of a series of three papers dealing with the *Aedes* fauna of the Philippine Islands. Part I (Knight and Hull, 1951*a*) contained the general introduction, the keys to the adults and larvae, and the treatments of the species belonging to the subgenera *Mucidus*, *Ochlerotatus*, and *Finlaya*. The part given here reports on the species of the subgenera *Skusea*, *Christophersiomyia*, *Geoskusea*, *Rhinoskusea*, and *Stegomyia*.

All of the necessary introductory information is given in Part I and only the explanations necessary for an understanding of the abbreviations and symbols used are repeated here.

A dagger (†) denotes types that have been examined by us.

The following abbreviations are used in the descriptions. Adult: *apn*, anterior pronotal lobe; *ppn*, posterior pronotal lobe. Larva: *isc*, inner or upper caudal hair of the anal segment; *osc*, outer or lower caudal hair of anal segment; *lh*, lateral hair on anal plate.

Figures are not drawn to scale.

The following abbreviations are used in the species distribution sections to denote the present locations of specimens examined. A.N.S.P., Academy of Natural Sciences of Philadelphia; C.A.S., California Academy of Sciences; U.S.N.M., U. S. National Museum; B.M., British Museum (Natural History); C.C., Cornell University; R.K.L., specimens from the collection of Naval Medical Research Unit No. 2 on which nothing has been previously published and which are now deposited in the U. S. National Museum, the Johns Hopkins University, the California Academy of Sciences, the British Museum, and the Knight collection.

SYSTEMATICS

Subgenus SKUSEA Theobald

1903. *Skusea* Theobald, Mon. Cul. 3: 291.
Genotype: *pembaensis* Theobald (Africa).

ADULT: Distinguished from all the other subgenera in the Philippines by the combination of being without special markings on the legs and scutum; having the male palpi as long as, or slightly longer than, the proboscis; and having the scales of the vertex and scutellum broad and flat. Other characters are: Dark species without special ornamentation. Male palpus straight, slender, a very few short hairs at the apices of the distal three segments. Dorsocentral and acrostichal bristles present. Paratergite not scaled. Lower mesepimeral bristles absent. Fore and mid-tarsal claws of male unequal, the smaller claw with a very small tooth; hind claws equal, simple. Tarsal claws of female equal, simple. *Terminalia:* Basistyle rather short and broad, with an apical lobe and with complicated basal lobes; dististyle appendage apical. Mesosome simple, tapered apically to a sharp point, outer portion more heavily sclerotized. Claspettes absent.

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[1] The opinions or conclusions contained herein are those of the authors and are not to be construed as official or reflecting the views of the Navy Department or of the naval service at large. Manuscript received October 23, 1951.

[2] Naval Medical Research Institute, Bethesda, Maryland. Lieutenant Commander and Lieutenant, respectively, MSC, USN.

LARVA: Separable from all the other aedine subgenera in the Philippines by the combination of the following: Antennal hair short, single, inserted at about the apical two thirds. Head hair 6 directly anterior to 5, 4 mesad of 6, 7 on a level between 5 and 6, all of them inserted far forward. Comb scales numerous, in a patch. Siphon without an acus; tuft single, hardly beyond middle; pecten teeth evenly arranged. Anal plate bare. Ventral brush consisting of 9–11 tufts, all but basal 1–3 tufts borne on a laterally unconnected barred area. Habitat—chiefly in axils and stumps of nipa palms in mangrove areas, but also in other types of container habitats in mangroves.

DISTRIBUTION: Five species are known at present, two of which occur in the Philippines. The others are *pembaensis* Theobald from Africa, *dasyorrhus* King and Hoogstraal from New Guinea, and *lamelliferus* Bohart and Ingram from the Caroline Islands. *A. kabaensis* Brug has been removed by us to the subgenus *Geoskusea*.

SYSTEMATICS: The four Pacific species are remarkably uniform in the general details of the adult and the larva. However, the African form differs markedly in the character of the mesosome, having it in the form of a simple tube. Also, the last two palpal segments are slightly thickened and hairy, and the female has lower mesepimeral bristles.

Aedes (Skusea) amesii (Ludlow)

1903. *Stegomyia amesii* Ludlow, N. Y. Ent. Soc., Jour. 11: 139 (female). Type locality: Philippines. Oras, Samar. Tacloban, Leyte. Twin Peaks, Banquet, Cagayan Province, Luzon (Ames). Type: 1 female (holotype) in U.S.N.M.† This is from Oras. No other type material remains.

1908. *Stegomyia Fusca* Leicester (nec Osten-Sacken, 1877), Cul. Malaya, p. 92 (males, female, larva). Type locality: Malaya. Klang (2 males). Pt. Swettenham (1 female) (Leicester). Type: 2 males, 1 female (cotypes) in B. M.†, 1 male with terminalia separated.

1917. *Skusea amesii* Ludlow. Edwards, Bul. Ent. Res. 7: 223. Description of male from Malay Peninsula. Different combination.

1925. *Aedes* (*Skusea*) *amesii* (Ludl.). Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 77, 78. In part. Different combination.

1928. *Aëdes* (*Skusea*) *furvus* Edwards, Bul. Ent. Res. 18: 274 (nom. nov. for *fusca*). Also, redescription of the male described in 1917.

1946. *Aedes* (*Skusea*) *amesii* (Ludlow). Hoogstraal and Chamberlain, Wash. Ent. Soc., Proc. 48: 125. Questioningly synonymized *furvus*. First description of larva.

ADULT: A very small dark brown species, with all broad dark vertex and scutellar scales and with small laterobasal pale spots on the abdominal tergites.

Male. Wing length 2.0–2.5 mm. *Head:* Proboscis all dark-scaled; slightly longer than the fore femur. Palpus approximately equal to the proboscis (exclusive of labellum) in length, measured range 0.75–1.0 times as long; dark; a very few short hairs at the apices of the distal three segments. Vertex covered with broad scales, these dark except for a transverse subdorsal white band which may be interrupted; a line of dark upright-forked scales along the nape, occasionally one or more along the anterodorsal margin also. *Thorax:* Scutal integument grayish brown; clothed with narrow brown scales. Scutellum with a prominent dense overlapping patch of broad dark scales on each lobe. *Apn* with a few broad dusky scales, *ppn* dorsally with broadened dark scales. Following pleural areas each with a patch of broad silvery-white scales: propleural, dorsal sternopleural, medioposterior sternopleural, and mesepimeral (below the hair tuft); pleural sclerites rather uniformly grayish brown. *Legs:* Dark-scaled. Fore and mid-tarsal claws unequal, the larger one simple and the smaller claw with a single very small tooth which is overlooked unless a slide mount is made; hind tarsal claws equal, simple. *Wings:* Brown-scaled. Halter stem pale, knob darker and with dusky scales. *Abdomen:* Tergites dark-scaled, I and II with a band of white scales along the lateral margin, III–VII with a basolateral patch of white scales. Sternites pale-scaled basally, brown-scaled apically. *Terminalia* (this description is adapted from Hoogstraal and Chamberlain, 1946: 125. The abbreviations are those used in their figure): Basistyle densely clothed with scales and numerous long setae; a conspicuous dense row of setae along the full length of the inner tergal margin. Basal lobe very large, divided into three sublobes as follows: a tergal sublobe (BLD) which is bulbous basally, constricted apically, and densely covered with fine hairs; a medial sublobe (BLM) with seven heavy flattened subequal filaments arising from separated elongate bases; and a stout sternal pedicel-like lobe (BLV) bearing two heavy flattened filaments. Basistyle apically with a knob-like tip, this extending beyond base of dististyle and bearing a cluster of striated pointed flattened filaments. Ninth tergite a narrow weakly sclerotized band, lacking lobes or setae.

Female. Differs from male as follows: Palpus approximately one sixth as long as the proboscis. Tarsal claws equal, simple.

LARVA: *Head:* Antenna smooth; antennal hair single, inserted at apical third and extending slightly beyond tip of antenna. Mouth brush with comb-like tips. Hair 4 with 6–10 branches; 5 single, lightly plumose, extending beyond the anterior margin of the head; 6 double (rarely triple), shorter than 5; 7 with 8–17, lightly plumose; 8 with 2–3; 9 with 3–6; 12 with 6–9, large, finely plumose; 13 single; 14 with 1–2; 15 with 2–3; 17 and 18 single; 20 with about 6 fine branches; hairs 4 and 6 well anterior to 7, 4 just within and posterior to 6, 5 lateral to 6. Mentum with 11–14 lateral teeth. *Thorax:* Prothoracic hair 1 with 2–4 branches. *Abdomen:* Dorsolateral hair on I with 4–9 branches; on II with 6–12. Lateral hair on I single; on II with 2–5, very short; on III–V with 3–4; on VI with 1–2. Pentad hair 1 with 3–5 branches; 3 with 2–4; 5 with 1–2. Comb with many small yellow narrow scales in a triangular patch, each scale rounded and usually slightly enlarged apically and with a complete fringe. Siphon with about apical one fifth paler than remainder; acus absent; index about 3.1 (after Hoogstraal and Chamberlain, 1946: 128); 11–17 pale, ventrally fringed pecten teeth, all approximately equal in length; siphon hair single, finely plumose, inserted just beyond middle and just beyond apical pecten tooth, extending slightly beyond apex of siphon; dorsolateral and ventrolateral basal valve hairs single (occasionally double), unusually long. Anal plate broadly incomplete; *lh* with 1–2 branches, nearly twice as long as the anal plate; *isc* with 7–9, *osc* single; ventral brush of 10 tufts (once 9 and once 11, however), each tuft with 4–8 branches, all but basal 1–3 tufts borne on a barred area; barred area not connected laterally. Anal gills bulbous or finger-like, broadly rounded apically; dorsal pair 1.4–1.8 times longer than ventral pair and 1.7–2.7 times longer than the anal plate.

BIONOMICS: The larvae were commonly collected in the axils and stumps of nipa palms in and along mangrove areas. Less commonly, they were found in tree holes, and once in a half coconut shell in a mangrove area. In the original description of *fusca*, Leicester reported collecting the larvae from the axils of the atap palm.

Adults were collected, always in or at the margins of mangrove areas, from around humans, from vegetation, and from the entrances of crab holes.

DISTRIBUTION: *Specimens examined.* R.K.L. Luzon: Subic Bay, Zambales Prov. (Rozeboom, MacMillan). Samar: Osmena (Rozeboom, Laffoon, Knight). Guirang (Zolick, Knight). Leyte: Hibuanurem Village (Knight, MacMillan). Palawan: Iwahig Penal Colony (Laffoon). Culion (Johnson). Mindanao:

Maasin Village, Zamboanga Prov. (Johnson, Laffoon, Knight). Jolo: Jolo (Johnson, Laffoon). A.N.S.P. Leyte: Tacloban (Roberts).

Literature records. Palawan: Puerto Princesa (Hoogstraal and Chamberlain, 1946: 125). Mindoro: San Jose (personal communication from E. S. Ross).

Known outside of the Philippines from Malaya, Sumatra, and Siam.

DISCUSSION: The systematics of this species have been fully discussed by Hoogstraal and Chamberlain (1946: 125). On the basis of Edwards' (1928: 274) description of *furvus* and the included figure of the male terminalia, they questioningly synonymized *furvus* to *amesii*. The synonymy was questioned because Edwards' figure did not show the setae of the apical lobe to be scale-like.

Since the appearance of the paper by Hoogstraal and Chamberlain, the senior author has had the opportunity of comparing the male terminalia of the Philippine species with that of one of the two cotype males of *furvus* and found them to be cospecific.

Aedes (Skusea) fumidus Edwards

Figs. 1, 2

1928. *Aëdes* (*Skusea*) *fumidus* Edwards, Bul. Ent. Res. 18: 274 (males, females, larvae). Type locality: Malaya. Singapore (Given). Type: Male (holotype) in B. M.† Terminalia separated.

1926. *Aedes amesii* (Ludl.). Edwards, Bul. Ent. Res. 17: 119. Larval description.

ADULT: Closely similar to *amesii*. Male terminalia markedly different, however.

Male. Wing length approximately 2.5 mm. Similar to *amesii*, but differing as follows: Palpus usually slightly longer than the proboscis. Mesepimeral scale patch confluent with the dorsal hair tuft. Hind femur usually with pale scaling ventrally on basal half of anterior surface. *Terminalia:* Basistyle densely clothed with scales (omitted in figure) and numerous long setae; a dense row of setae along the full length of the inner tergal margin. Basal lobe conspicuous, divided into three sublobes as follows: a tergal elongate strap-like sublobe (BLD), with prominent stout setae apically and numerous hairs sternally (these latter not figured); a medial sublobe (BLM) with four stout filaments arising from separate elongate bases; and a sternal sublobe (BLV) bearing two heavy flattened filaments (omitted from figure of terminalia but shown detached in Fig. 1*a*). Basistyle sternally with a mesally directed setose double subapical lobe (SAL), and with an apical lobe (AL) that bears two slender elongate scales. Ninth tergite a narrow, weakly sclerotized band, lacking lobes or setae.

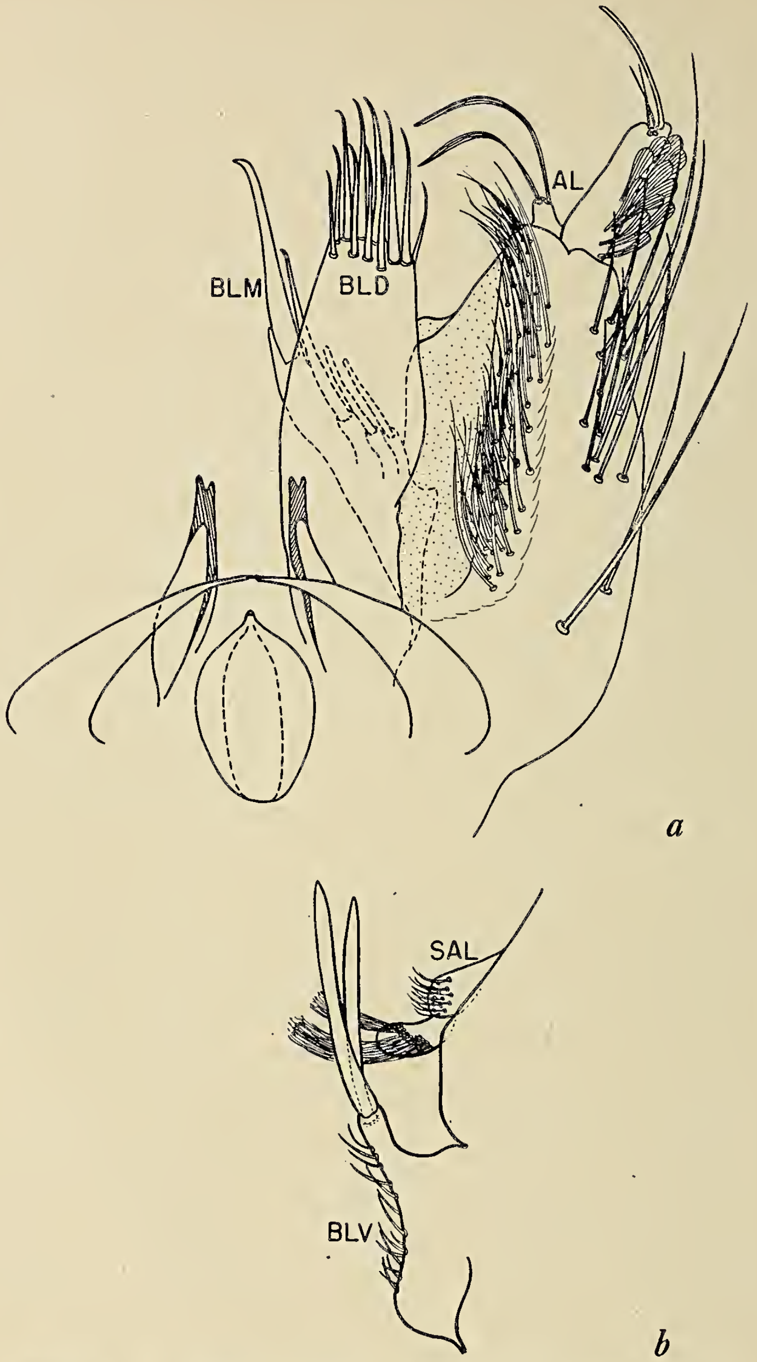

FIG. 1. *A.* (*Skusea*) *fumidus*. Male terminalia (Luzon). *a*, Dorsal aspect. Scales omitted from basistyle. The two most ventral lobes, BLV and SAL, are omitted. *b*, Dorsal aspect of lobes BLV and SAL.

Female. Similar to the female of *amesii*, but differing from it (as in the males) in the color of the hind femoral scaling and in the extent of the mesepimeral scale patch.

LARVA: *Head:* Antenna smooth, nearly uniform in diameter throughout; antennal hair single, fine, inserted at about distal one third and extending just beyond apex of antenna. Mouth brushes with comb-like tips. Hair 4 with 13–20 branches; 5 single, rarely double; 6 with 2–3 (4–5 branched in 2 specimens from Subic Bay, Luzon; coll. 1068); 7 with 6–17; 8 double; 9 with 3–4; 12 with 5–8; 13 and 14 single; 15 with 2–3; 17 and 18 single; 20 with 2–6. Mentum with 11–15 lateral teeth. *Thorax:* Prothoracic hair 1 with 3–8 branches; 2 single; 3 with 3–5. Mesothoracic hair 9 with 12–18 branches; 10 and 12 single, stout, long; 11 not seen. Metathoracic hair 9 with 5–9 branches; 10 single, stout; 12 single, much reduced; 11 not seen. *Abdomen:* Dorsolateral hairs on I and II with 6–7 branches (occasionally 5–9). Lateral hair on I single; on II to V with 2–6 branches; on VI single or double. Pentad hair 1 with 3–5 branches; 3 with 3–4; 5 with 1–3. Comb of 80 to 100 small scales in a triangular patch, the entire margin of the scales fringed. Siphon smooth, sclerotization incomplete basally, without acus, index 2.4; 7–15 pecten teeth in a row, with the basal 1–4 teeth off the sclerotized portion of the siphon, the teeth each fringed along entire ventral margin; siphon hair single, rather stout. Anal plate smooth, covering little more than the dorsal area of the segment; *lh* single, stout; *isc* with 5–9 branches, *osc* single; ventral brush of 10 tufts (one specimen with 11) with 1 or 2 off the barred area basally, the tufts with 5–8 branches; barred area not connected laterally. Anal gills finger-like, the dorsal pair about 1.3 times longer than ventral pair, and 2.1–3.5 times longer than the anal plate.

BIONOMICS: The adults were captured in vegetation near a river. The larvae were collected from tree holes, nipa axils and stumps, bamboo stumps, and artificial containers.

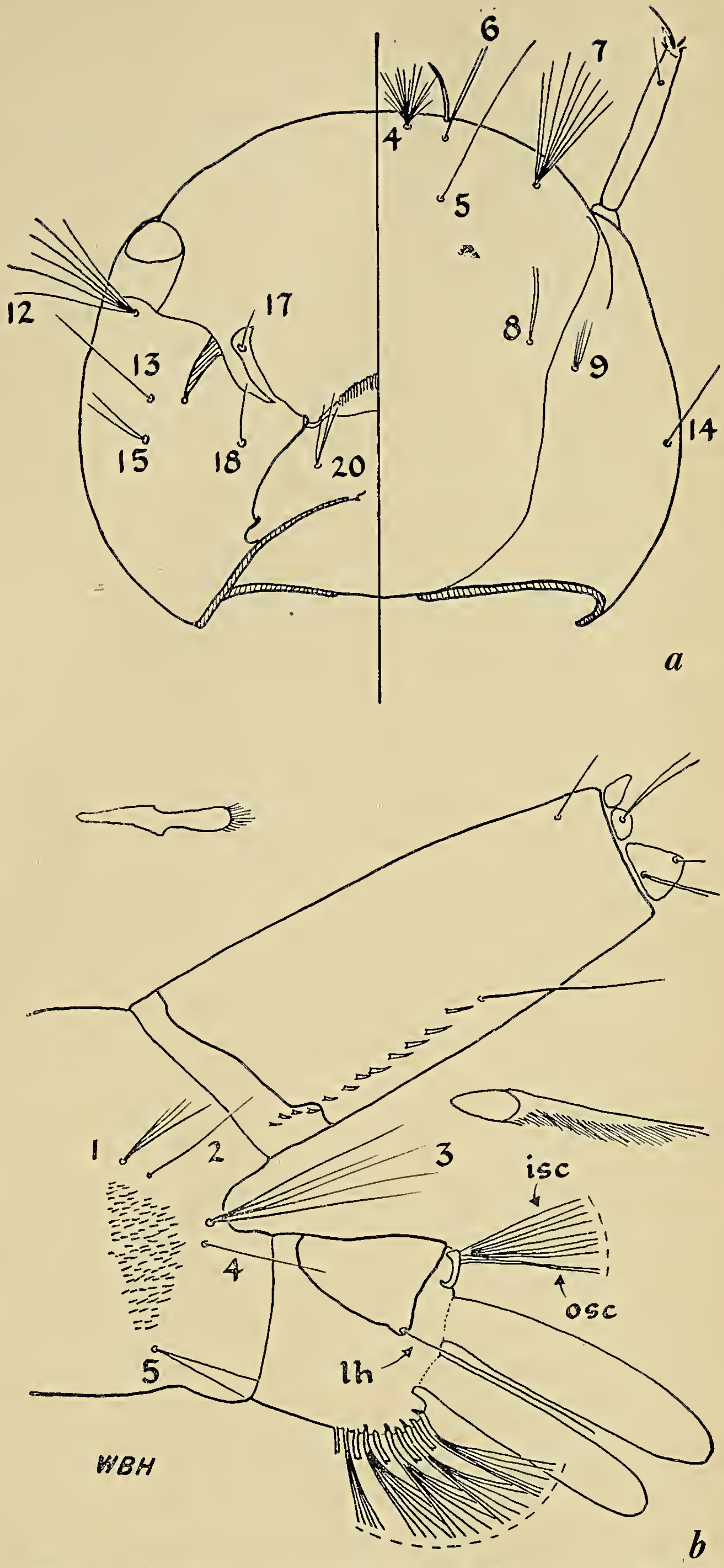

FIG. 2. *A.* (*Skusea*) *fumidus.* Larva (Luzon). *a*, Head; *b*, terminal segments.

DISTRIBUTION: *Specimens examined.* R.K.L. (many adults with assoc. skins). Luzon: Olongapo, Subic Bay, Zambales Prov. (Rozeboom, MacMillan).

Outside of the Philippines known from Malaya, Celebes, Boeton, and Kabaena.

DISCUSSION: This species has not previously been reported from the Philippines. The identification was confirmed by comparison of specimens with the type.

Subgenus CHRISTOPHERSIOMYIA Barraud

1923. *Christophersiomyia* Barraud, Indian Jour. Med. Res. 10: 786. Genotype: *thomsoni* Theobald (India).

ADULT: Ornate species. Distinct from the other Philippine subgenera by the combination of the following characters: short palpi in both sexes (slightly over a quarter as long as proboscis), white-marked proboscis, narrow scales on *apn*, banded hind tarsi, and undivided mesosome. Other characters: Scales of vertex and scutellum all broad. Scutum with white markings. No dorsocentral, acrostichal, or prescutellar bristles. Paratergite scaled. Lower mesepimeral bristles present. Tarsal claws in both sexes small, all equal, and each unidentate. *Terminalia:* Basistyle with a slight basal lobe, no apical lobe. Dististyle appendage apical. Mesosome simple, not divided into toothed lateral lobes. No claspettes.

LARVA: Unknown for the single Philippine species. Described by Edwards (1932: 159) as follows: "Antenna spicular, with branched hair on shaft. Siphon index about 3; tuft near the middle; pecten evenly arranged; acus small or absent. Comb teeth in a single close-set row. Anal plate narrowly incomplete. Ventral brush short." Barraud (1934: 213) shows, for *thomsoni* (Theobald), head hairs 4, 6, and 7 roughly on a horizontal level, with hair 5 nearly directly posterior to 6. Habitat—tree and rock holes.

DISTRIBUTION: Confined to the Oriental Region. Three species are known form India and Ceylon, and one from the Philippines.

SYSTEMATICS: The four known species are so closely related as to suggest that they form either a polytypic species or a superspecies. Even so, a subgeneric position is desirable for them because of their markedly isolated position within the genus *Aedes*.

Aedes (Christophersiomyia) brayi Knight

1947. *Aedes* (*Christophersiomyia*) *brayi* Knight, Biol. Soc. Wash., Proc. 60: 73 (male, female). Type locality: Philippines. San Jose, Nueva Ecija Prov., Luzon (Bray). Type: Male (holotype) in U.S.N.M.† Terminalia mounted.

DISTRIBUTION: *Specimens examined.* Known only from the type series of one male and one female. Luzon: San Jose, Nueva Ecija Prov.

DISCUSSION: *A. brayi* differs from the other known species of *Christophersiomyia* on the markings of the proboscis, femora, tibiae, and tarsi.

The larva is unknown.

Subgenus GEOSKUSEA Edwards

1929. *Geoskusea* Edwards, Bul. Ent. Res. 20: 342. Genotype: *fimbripes* Edwards (New Britain).

ADULT: Male palpi either about one fourth as long as the proboscis, or else approximately two thirds as long. Scales on vertex, and usually those on the scutellum also, broad and flat. Dorsocentral and acrostichal bristles present. Paratergite not scaled. Lower mesepimeral bristles absent; however, numerous fine hairs present on one or more of the pleural sclerites. Fore and mid-tarsal claws of male unequal, the larger claw of fore legs bidentate and the smaller claw unidentate, both mid-tarsal claws unidentate; hind tarsal claws equal, simple. Female tarsal claws equal, simple. *Terminalia:* Basistyle long and slender, with a more or less detached subbasal or median setose lobe. Dististyle appendage apical. Mesosome simple, scoop-like as in *Ochlerotatus*. Claspettes absent.

LARVA: Unknown for the single Philippine species. The larvae of *daggyi* Stone and Bohart from the New Hebrides and *kabaenensis* Brug from the Celebes have been described and have the following characters: Antennal hair 2–4 branched, inserted near the middle. Head hair 6 placed slightly posterior to level of 7, 5 quite near to 6 and obliquely mesad and posterior to it, 4 near the midline and on or near to a level with 6. Comb scales numerous, in a patch. Siphon with an acus; hair tuft branched and beyond middle; pecten teeth evenly arranged. Ventral brush of 12 tufts. Habitat—crab holes.

DISTRIBUTION: The seven known species are confined to the Australasian and Oriental Regions. Only two species are recorded from the Oriental Region, one from the Celebes and one from the Philippines.

SYSTEMATICS: The systematics of this subgenus have been discussed by Knight and Hull (1951). They list the following species as belonging here: *fimbripes* Edwards, *longiforceps* Edwards, *tonsus* Edwards, ? *daliensis* (Taylor), *daggyi* Stone and Bohart, *kabaenensis* Brug (formerly placed in *Skusea*), and *baisasi* Knight and Hull.

Aedes (Geoskusea) baisasi Knight and Hull

1951. *Aedes* (*Geoskusea*) *baisasi* Knight and Hull, Pacific Sci. 5: 197 (males, females). Type locality: Philippines. Iwahig Penal Colony, Palawan Island (Laffoon). Type: Male (holotype) in U.S.N.M.† Terminalia not separated.

DISTRIBUTION: *Specimens examined.* Palawan: Iwahig Penal Colony. Mindanao: Zamboanga, City of Zamboanga Prov. Mindoro: nr. Mangarin Bay, San Jose. Samar: Pintanahon and Osmena.

DISCUSSION: *A. kabaenensis* Brug from the Celebes is closely related to *baisasi*, differing from it mainly in possessing only 1–3 thick setae and 1–2 bristles on each lobe of the ninth tergite, and in having the slender elongate hairs of the basal lobe of the basistyle confined to the apex of the lobe. It seems likely that when more material is available, *kabaenensis* and *baisasi* will prove to be members (subspecies) of a single polytypic species.

A. baisasi and *kabaenensis* differ markedly from the other known *Geoskusea* species in having the male palpi approximately two thirds as long as the proboscis. Also, conspicuous differences occur in the male genitalia.

The larva is unknown.

Subgenus RHINOSKUSEA Edwards

1929. *Rhinoskusea* Edwards, Bul. Ent. Res. 20: 342. Genotype: *longirostris* Leicester (Malaya).

ADULT: A small dark unornamented species. Differs from all the other *Aedes* species in the Philippines in having the first hind tarsal segment as long as, or longer than, the tibia. Palpi in both sexes very short. Scales of vertex and scutellum all broad and flat. Dorsocentral and acrostichal bristles present. Paratergite not scaled. No lower mesepimeral bristles. Male with tarsal claws slightly unequal on all legs, the larger bearing a small basal tooth; female claws equal and simple on all legs. *Terminalia:* Basistyle with basal and apical lobes. Dististyle appendage apical. Mesosome simple. Claspettes absent.

LARVA: Antennal hair tuft with 4–7 branches. Comb with 50–75 scales arranged in a patch. Siphon with an attached acus, pecten evenly arranged, hair tuft inserted near apex. Anal plate incomplete. Ventral brush with 10 tufts, all but basal one borne on a barred area, this area not connected laterally. Habitat—crab holes and brackish ground pools.

DISTRIBUTION: The one known species occurs in both the Australasian and Oriental Regions.

Aedes (Rhinoskusea) longirostris (Leicester)

Figs. 3, 4

1908. *Ficalbia Longirostris* Leicester, Cul. Malaya, p. 228 (males, females, larvae). Type locality: Malaya. Kuala Klang (Leicester and Daniels). Type: 2 males, 4 females (cotypes) in B. M.†

1919. *Uranotaenia hilli* Taylor, Linn. Soc. N. S. Wales, Proc. 43: 841 (2 males). Type locality: Australia. Darwin, Northern Territory (Hill). Type: Male (holotype) probably in School of Public Health and Tropical Medicine, University of Sydney.

1924. *Aëdes* (*Skusea*) *longirostris* (Leic.). Edwards, Bul. Ent. Res. 14: 391. Synonymy of *hilli*.

Adult and larva described by Edwards (1929: 342) and Barraud (1934: 216), and the larva by Edwards (1926: 120).

ADULT: A small dark species without conspicuous markings. Abdomen of female with basolateral pale patches on some segments.

Male. Wing length approximately 1.9–2.1 mm. *Head:* Proboscis dark-scaled; distinctly longer than the fore femur. Palpus dark, only about one eighth as long as the proboscis. Torus bare of scales, however a few hairs may be present. Vertex with broad dark scales, some broad pale scales laterally, and a line of pale scales along eye margin (usually inconspicuous); a row of dark upright-forked scales along the nape. *Thorax:* Scutum with brown scales. Scutellar lobes with broad dark scales. *Apn*, *ppn*, and pleuron bare of scales; no lower mesepimeral bristles; pleural sclerites grayish brown. *Legs:* Dark, femora partially pale posteriorly. Tarsal claws of all three legs with one slightly larger than the other, the larger claw in each case bearing a slender small tooth near the base (can be seen only on a slide mount). *Wings:* Dark-scaled. Halter stem pale, knob darker and with dusky scales. *Abdomen:* Tergites brown-scaled, lateral margin of I usually with a few dark scales. Sternites brown-scaled. *Terminalia:* Basistyle with a hairy lobe near apex and with two large processes arising basally from the inner surface. Dististyle hairy on apical one third and with a small double appendage. Mesosome simple. Ninth tergite without setae.

Female. Wing length 2.1–2.7 mm. Resembles the male in all details except that basolateral pale patches are present on some of the tergites. Also, the tarsal claws are all equal and simple.

LARVA: *Head:* Antenna spiculated, broadest at base and gradually tapering to apex; antennal hair tuft with 4–7 branches, inserted beyond middle and extending to beyond apex of antenna. Hair 4 very small, with 3–5 branches; 5 with 5–7; 6 double; 7 with 8–14; 8 with 2–3; 9 with 2–4; 12 with 3–7; 13 double, rarely with 3; 14 with 2–3; 15 small, double, occasionally with 1–3; 17 single; 18 single, rarely double; 20 with 2–4. Mentum with 9–12 lateral teeth. *Thorax:* Prothoracic hairs 1, 2, and 3 all single. Mesothoracic hair 9 with 5–7 branches; 10 and 12 single, long, stout; 11 single, very small. Metathoracic hair 9 with 2–3 branches; 10 single, long, stout; 12 single, much reduced; 11 single, very small. *Abdomen:* Dorsolateral hairs on I and II with 3 branches, rarely 2–4. Lateral hair on I single; on II small, with 2–4 branches; on III–VI double, rarely with 3 branches. Pentad hair 1 with 3–6 branches; 2 and 4 single; 3 with 4–9; 5 with 9–13. Comb of 50 to 75 scales in a triangular patch,

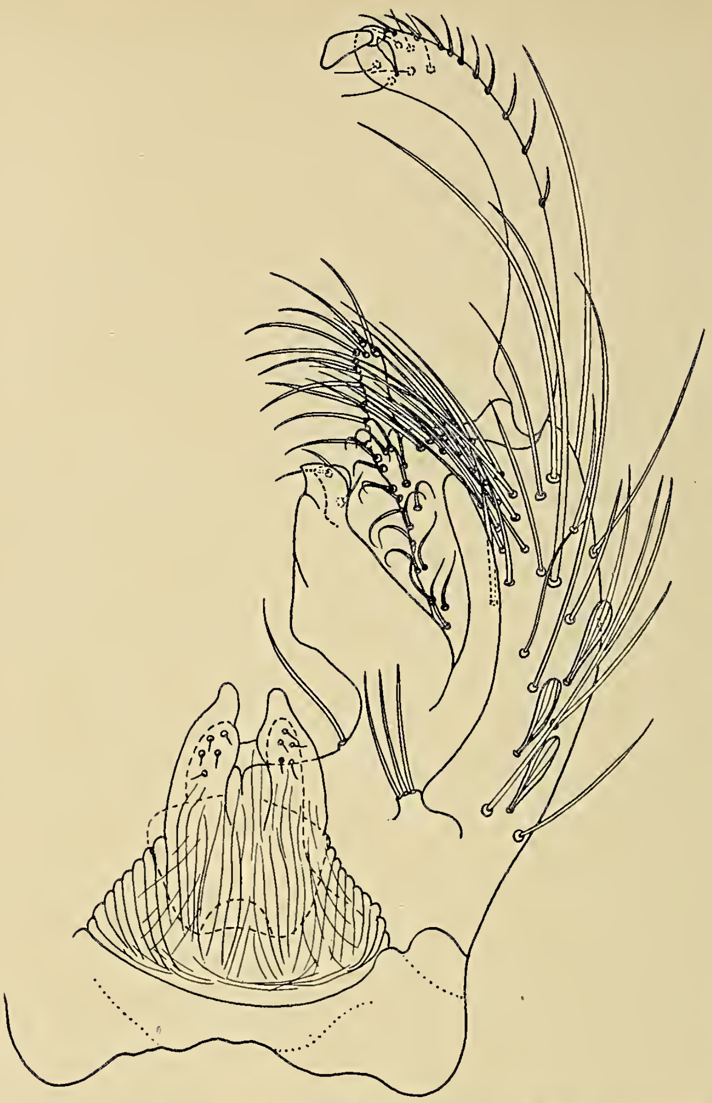

FIG. 3. *A.* (*Rhinoskusea*) *longirostris*. Male terminalia (Samar).

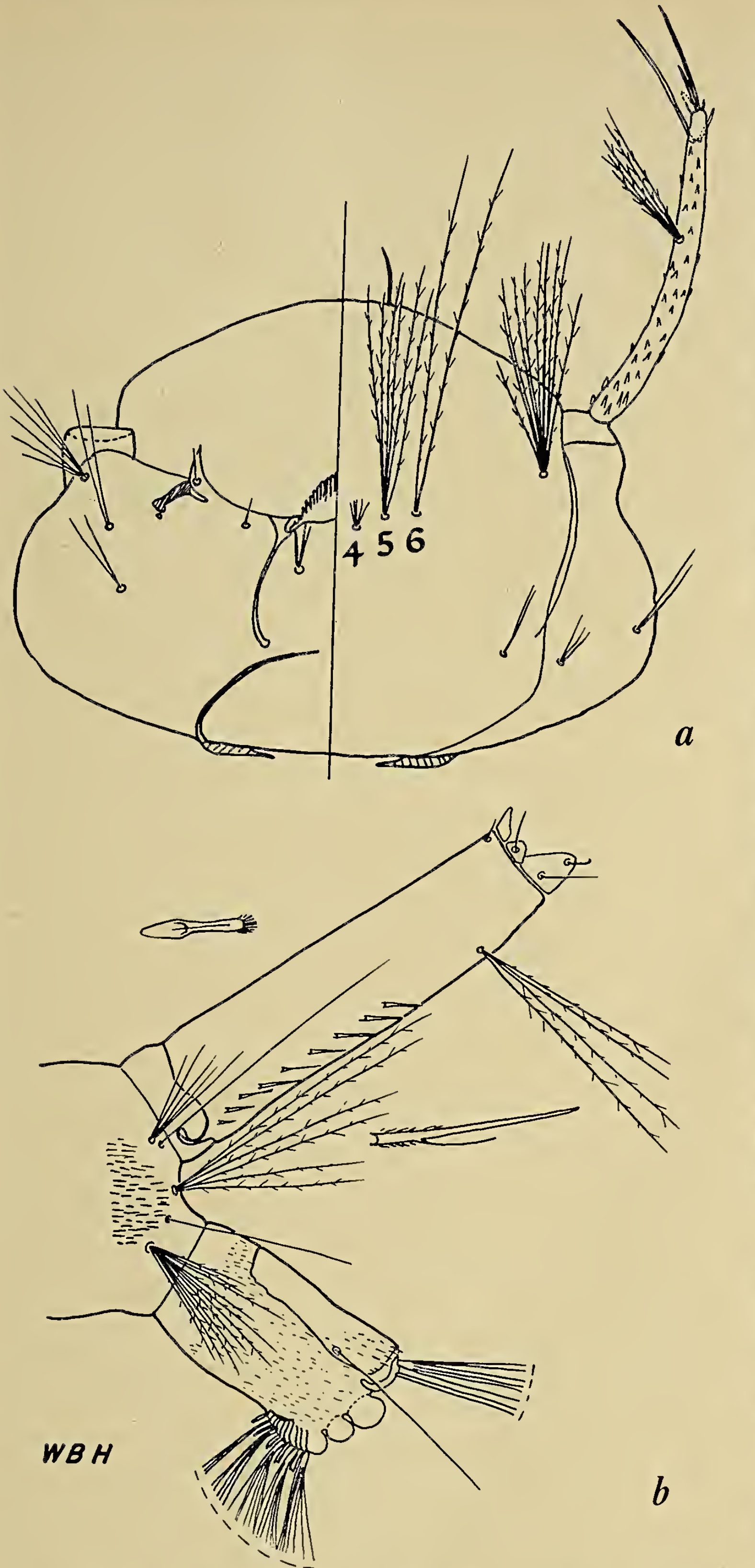

Fig. 4. *A.* (*Rhinoskusea*) *longirostris*. Larva. *a*, Head (Samar); *b*, terminal segments (Balabac).

the scales with blunt fringed tips. Siphon smooth, with an attached acus, index 3.4–3.8; 8–15 pecten teeth, each tooth long slender and fringed along basal portion; siphon hair tuft with 5 branches, rarely 3–6, inserted near apex. Anal plate spiculated, covering little more than the dorsal area of the segment; *lh* single; *isc* with 3–6 branches, *osc* single; ventral brush of 10 tufts with 1 off the barred area basally, the tufts with 2–8 branches; barred area not connected laterally. Anal gills small and bulbous, subequal, the dorsal pair 0.15–0.24 as long as anal plate.

BIONOMICS: The adults were found resting in crab holes. The larvae were collected from brackish pools in swamps and near the beach, from brackish water in a beached boat, from a tin plate in a grassy area, and from a depression on a fallen log. The larvae were collected from brackish water in crab holes on Mindoro by E. S. Ross. Causey (1937: 413) reported a larval collection from a brackish rock pool in Siam.

DISTRIBUTION: *Specimens examined.* R. K. L. Samar: 3 males, 8 females, 19 sets assoc. skins, Pintanahon, nr. Osmena (Laffoon). Mindanao: 1 male, 2 females, Zamboanga, City of Zamboanga Prov. (Laffoon, Knight). Palawan: 1 female, Iwahig Penal Colony (Laffoon). Larvae, Tacburos (Fitzgerald). Balabac: 2 males, 1 female, larvae, Cape Melville (Laffoon, Johnson, Howell, Fitzgerald). Philippine Bureau Health Coll. Palawan: 2 males, 1 female, Iwahig (Nuno). C.A.S. Mindoro: 1 male, 1 female, 2 sets assoc. skins, nr. Mangarin Bay, San Jose (Ross).

Outside the Philippines it is known from northern Australia, Malaya, Siam, and the Andaman Islands.

DISCUSSION: This species has not previously been reported from the Philippines.

Subgenus STEGOMYIA Theobald

1901. *Stegomyia* Theobald, Mon. Cul. 1: 283. Genotype: *fasciata* Fabricius.

1904. *Scutomyia* Theobald, Entomologist 37: 77. Genotype: *albolineata* Theobald (Australasian and Oriental Regions).

1908. *Pseudostegomyia* Ludlow, Mosq. Philippine Isls., p. 10. Genotype: *gardnerii* Ludlow (Philippines).

1925. *Catatassomyia* Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 71. Genotype: *meronephada* Dyar and Shannon (Philippines).

ADULT: Dark species, with white markings on thorax and legs. Male palpi varying in length from equaling the proboscis to being only one half as long; bare of hairs except for a few bristles at the apices of III–V; straight or with IV–V upturned. Scales on vertex and scutellum all broad and flat. However, in some species the vertex possesses a diamond-shaped medioanterior area of narrow white scales which extends anteriorly between the eyes. Acrostichal bristles absent, a few dorsocentrals present in some species. Paratergite with or without scaling. Lower mesepimeral bristles absent. Male tarsal claws unequal on fore and midlegs, unidentate (the smaller simple in *albopictus*); equal, simple on hind legs. Female tarsal claws equal; fore and mid simple or unidentate, hind simple. *Terminalia:* Basistyle without apical lobe (except in *m.* var. *perplexus*); basal lobe either a plaque on medial surface or a largely detached columnar structure, setose. Claspettes absent. Mesosome divided into two lateral plates, each of which bears numerous teeth laterally.

LARVA: Antennal hair with 1–5 branches. Head hair 5 posteriorly on or near to a longitudinal level with 6 and slightly posterior to the level of the antennal bases, 4 just anterior and mesad of 6, 7 slightly posterior to level of antennal bases. Comb teeth stout, thorn like, in a row. Siphon with acus present or absent; pecten teeth evenly spaced. Ventral brush with 8–12 single or double hairs (up to 6-branched in a few species, however), barred area may or may not be laterally connected (in *desmotes* the lateral bar is modified into a small plate). Habitat—a wide variety of natural and artificial container habitats (tree holes, bamboo stumps, leaf axils, etc.). One species is commonly found in rock pools.

DISTRIBUTION: Edwards (1932: 161) gives the distribution of this subgenus as follows: "Except that *A. aegypti* has been artificially spread by commerce, the subgenus *Stegomyia* is confined to the tropical and subtropical regions of the old world, chiefly the Ethiopian and Oriental Regions." At present 15 species and subspecies are known from the Philippines.

SYSTEMATICS: Edwards (1932: 161) divided the subgenus into four groups, of which all except Group D are represented in the Philippines. Knight and Hurlbut (1949: 26) raised the *albolineatus* complex to the status of a full additional group (Group E) and divided Group C into three subgroups.

Group A (*aegypti*-group: *Stegomyia* s. str.). Scutum with a pair of crescent-shaped, oval, or rounded patches of white scales in front of the anterior fossae, and with more or less distinct traces of one or two median pale lines. Dististyle with a terminal appendage. Paraprocts each with a prominent mesal ventral arm basally. Represented in the Philippines by *aegypti*.

Group B (*w-alba*-group). Scutal ornamentation various; usually patches of white or yellow scales are present, and these are seldom arranged as in Group A, and there is never a distinct narrow median white stripe. Dististyle appendage present or absent, if present it is terminal. Paraprocts without vertical arm near base, except in *desmotes*. Represented in the Philippines by *aurotaeniatus*, *desmotes*, *gardnerii*, and *meronephada*.

Group C (*scutellaris*-group). Scutum with a conspicuous white median line (this sometimes broadened anteriorly), but without large white patches. Dististyle appendage terminal. Paraprocts without vertical arm near base. Knight and Hurlbut (1949: 26) divided Group C into three subgroups as follows: Subgroup I, *scutellaris* s. str. Abdominal tergal markings with the more mesal portions subbasal. Postspiracular scales lacking. Scutal longitudinal median line relatively slender. Pleural scale patches arranged into two rather well-defined longitudinal bands (not true of *gurneyi* Stone and Bohart). Represented in the Philippines by *paullusi* and *scutellaris*. Subgroup II, *albopictus*. Abdominal tergal markings basal. Postspiracular scales lacking. Scutal longitudinal median line relatively slender. Pleural scale patches not arranged in two well-defined longitudinal bands. Represented in the Philippines by *albopictus*. Subgroup III, *mediopunctatus.* Abdominal tergal markings basal. Postspiracular area scaled. Scutal longitudinal median line quite broad. Pleural scale patches not arranged in two well-defined longitudinal bands. Represented in the Philippines by *mediopunctatus* var. *perplexus.*

Group D (*vittatus*-group) is not represented in the Philippines.

Group E (*albolineatus*-group). Similar to Group C but differing as follows: Vertex with a median anterior diamond-shaped area of narrow white scales. Pleuron with a single broad longitudinal band of broad white scales that begins on the propleuron and extends to the upper mesepimeron. Hind tarsi with only the first three segments marked or banded (occasionally a few white scales on IV). Dististyle appendage well-removed from apex. Represented in the Philippines by *albolineatus*, *arboricolus*, *bambusicolus*, *boharti*, *hoogstraali*, and *laffooni.*

Aedes (Stegomyia) aegypti (Linnaeus)

Fig. 5

1762. *Culex aegypti* Linnaeus, in Hasselquist's Reise nach Palestina, p. 470 (female?). Type locality: Egypt. Type: Nonexistent.

1906. *Stegomyia fasciata persistans* Banks, Philippine Jour. Sci. 1: 996 (male, female). Type locality: Philippines. Not specifically given, but the following listed: Manila, Negros Occidental, Iloilo (Banks). Type: Nonexistent. However, 2 males, 5 females coll. by Banks and labeled as *persistans* are in the U.S.N.M.

1911. *Duttonia alboannulis* Ludlow, Psyche 18: 132. Type locality: Philippines. Mindanao. Type: Female (lectotype) in U.S. N.M.† A subsequent selection by Dyar and Shannon (1925: 75).

Edwards, 1932: 161 (systematics). Bonne-Wepster and Brug, 1932: 13 (adult, larva, biology). Barraud, 1934: 221 (adult, larva, variations). Bohart and Ingram, 1946: 6, 11, 22, 27, 37, 66 (adult, larva, bionomics, Pacific distribution).

ADULT: A medium-size brown, or black, and white species; with a dark proboscis, hind tarsal segments I–IV each basally banded, hind tarsal segment V all white, the vertex scales broad except on the nape, the numerous white pleural scale patches not forming definite bands, and pale dorsobasal bands and separate lateral white spots on the tergites.

Male. Wing length about 2.5–2.7 mm. *Head:* Proboscis dark. Palpus slightly longer than the proboscis, including the labella; II–V each with a basal white band, the bands on II–III incomplete ventrally and those on IV–V incomplete dorsally. Torus with broad white scales. Vertex with medial (this patch extending anteriorly to between the tori), subdorsal (a line of white scales connects this patch to the medial patch along the eye margin), and lateral areas of broad pale scales and with two alternating patches of broad dark scales; some narrow pale scales and a line of dusky upright-forked scales on the nape. *Thorax:* Scutum covered with narrow scales, all dark except for the following pale markings; 2 thin admedian longitudinal lines of narrow yellowish scales from near anterior margin to shortly before the prescutellar space, a small anteromedian spot of narrow pale scales, a rather broad crescent-shaped area of broad curved silvery scales on the lateral margin over *ppn* and along the scutal angle, a thin line of narrow white scales extending to the posterior margin from the end of the scutal angle, a patch of broad-curved white scales before the wing base with a thin posterior extension above the wing base, and some narrow pale scales around the prescutellar space. Scutellum covered with broad white scales, some apical broad dark scales on the mid-lobe. *Apn* with broad white scales, *ppn* with narrow dark and pale scales, a patch of broad white scales posteroventrally. Following pleural areas each with a patch of broad white scales: propleural, subspiracular (2 patches here, one being along the sternopleural margin and the other just anterior to the first), paratergite, prealar, dorsal sternopleural, medioposterior sternopleural, and upper mesepimeral (over the upper two thirds and covering base of dorsal hair tuft, the whole patch being somewhat V-shaped and sometimes with a small interruption medially). *Legs:* Fore and mid-tarsi with basal white bands on I–II, sometimes also some basal pale scales on III of the mid-tarsus. Hind tarsus with basal white bands on I–IV, V all white; the bands on I–II covering about one third of the segment, on III two fifths, and on IV about three fourths. *Wing:* Dark-scaled. A small basal spot of white scales on the costa. *Abdomen:* Tergite I pale-scaled except for a subdorsal basal dark patch, III–VI with basal median white bands, apical pale scaling present on II–IV; I with a complete band of pale scales on the lateral margin, II–VII each with a basal or slightly subbasal white spot just before the lateral margin. *Terminalia:* Basistyle with a large heavily setose lobe on inner surface. Dististyle appendage apical. Claspette absent. Paraproct very distinctive in possessing a prominent mesal-ventrally projecting arm. Ninth tergite deeply cleft medially, the lobes each bearing a small tuft of short setae.

Female. Length of wing about 3 mm. Palpus approximately one sixth the length of the proboscis, apical half white-scaled. Clypeus dorsally with 2 spots of white scaling. Vertex frequently paler than in male, the subdorsal dark band being largely obliterated by pale scaling. Dark scutal scaling paler than in male, being yellowish brown. Tarsal claws equal, fore and mid each unidentate, hind simple. Tergite II with a few dorsal pale scales basally or sometimes even with a well-developed basal band; apical pale scales on all the tergites.

LARVA: *Head:* Antenna smooth, evenly shaped throughout; antennal hair single, small, inserted medially. Mouth brush with comb-like tips. Hair 4 with 4–7 branches; 5, 6, 7 (rarely double), 8, 9, 13, and 14 single; 12 with 2–3; 15 with 1–4; 17, 18, and 20 with 1–2. Mentum with 11–14 lateral teeth. *Thorax:* Prothoracic hair 1 with 2–3 branches; 2 single; 3 double. Mesothoracic hair 9 with 2–3 branches; 10 and 12 single, long stout; 11 very small; a stout elongate curved spine at base of tubercle. Metathoracic pleural hair group similar to above except that hair 12 is reduced. *Abdomen:* Dorsolateral hair on I with 3–4 branches; on II with 2–3. Lateral hair on I single; on II to V double; on VI single or double. Pentad hair 1 with 3–4 branches; 2 and 4 single; 3 with 5–6; 5 with 2–5. Comb with 6–10 teeth, each tooth with prominent denticles at base of main shaft. Siphon smooth, without acus, index 2.5; 10–15 pecten teeth evenly spaced in a straight line, with ventral and occasionally dorsal denticles;

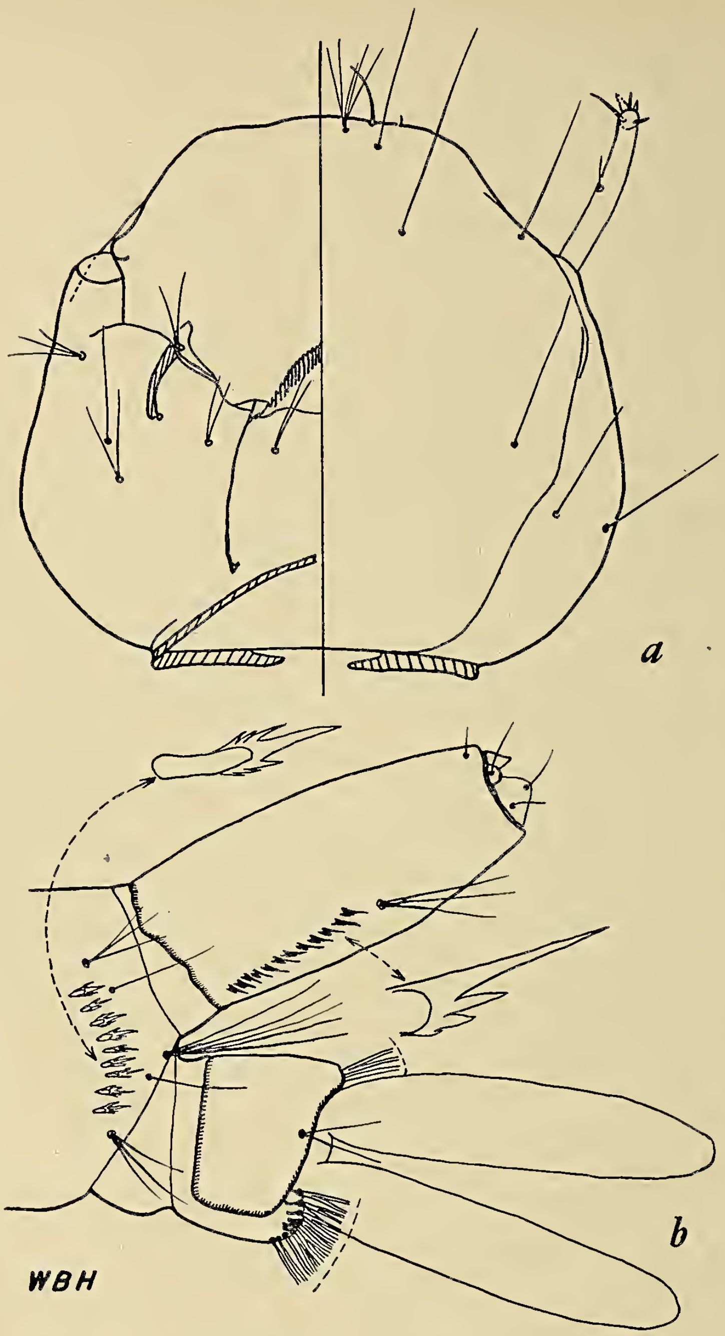

FIG. 5. *A.* (*Stegomyia*) *aegypti.* Larva (Mindoro). *a,* Head; *b,* terminal segments.

siphon hair tuft with 3 branches. Anal plate smooth, incomplete; *lh* single or double; *isc* with 2–3 branches, *osc* single; ventral brush of 10 tufts, each of which is forked near the base, all borne on a barred area; barred area may be partially connected laterally. Anal gills rounded at tips, subequal, approximately 3 times longer than anal plate.

BIONOMICS: In the Pacific portion of its range this mosquito apparently always occurs near habitations, the larvae almost always being found in artificial containers and the adults entering houses to bite humans. Bohart and Ingram (1946: 6) have presented an excellent review of the biology and disease relationships of this species in the Pacific areas.

DISTRIBUTION: *Specimens examined.* R.K.L. Luzon: 1 male, with assoc. skins, Olongapo (Santa Rita), Subic Bay, Zambales Prov. (Zedeck). U.S.N.M. Luzon: 7 males, Camp Stotsenberg, Pampanga Prov. (Parsons). Eight males, 1 female, Samal, Bataan Prov. 1 male, 2 females, Hagonoy, Bulacan Prov. 1 female, Manila, Manila Prov. 2 males, 4 females, Camp Elridge, Laguna Prov. Leyte: 3 males, Ormoc (Holliday). Panay: 1 female, Iloilo (McCoy). Cebu: 4 males, Cebu. Mindanao: 1 female, Cotabato, Cotabato Prov. (Holliday). 1 male, Pettit Barracks, Zamboanga, City of Zamboanga Prov. (Visaya, Conde). Mindoro: 7 males, Calapan. Jolo: 2 females, Jolo. C. C. Luzon: 7 males, 9 females, Agoo, LaUnion Prov. (Franclemont). A.N.S.P. Leyte: 7 males, 8 females, 4 larvae, Dulag (Roberts).

Literature records. Mindoro: Caminawit Pt. (Penn, 1948: 245). Leyte: Tolosa (Bick, 1949: 2). Panay: Guimeras Isl. (Ludlow, 1904: 233). Negros: Negros Occidental (Banks, 1906: 996).

Outside of the Philippines *aegypti* is known generally from the tropical and subtropical zones of the world.

DISCUSSION: The type of *alboannulis* is in fragments, and is so oiled as nearly to be unrecognizable.

Aedes (Stegomyia) aurotaeniatus
Edwards

1906. *Stegomyia aurostriata* Banks (nec Doleschall, 1857), Philippine Jour. Sci. 1: 995 (females). Type locality: Philippines. Volcano Canlaon, Mt. Siya-Siya, at 760 m. alt., Negros Occidental Prov., Negros Island (Banks). Type: Female (cotype) in B. M.† Here designated lectotype (24–VI–06. 1908–243). Banks's types in Manila are nonexistent.

1922. *Aedes* (*Stegomyia*) *aurotaeniatus* Edwards, Indian Jour. Med. Res. 10: 256, 464 (nom. nov.).

ADULT: Scutum with a pattern of longitudinal golden lines. Tarsi all dark, except I of hind legs which has a basolateral dull white area.

Male. Unknown.

Female. Wing length 3.5 mm. *Head:* Proboscis dark. Palpus about one seventh to one eighth the length of the proboscis; dark. Torus scaled. Vertex broad-scaled, pale except for a large subdorsal dark patch; upright-forked scales on the nape. *Thorax:* Scutum brown-scaled, marked as follows: a very narrow median golden line, scarcely perceptible anteriorly, that is broadened posteriorly across the prescutellar space; a subdorsal golden band that bends outwardly anteriorly and inwardly posteriorly, tapered posteriorly; a short lateral stripe of golden scales before the wing base. Scutellar mid-lobe with a median patch of broad creamy scales bordered by dark brown ones, lateral lobes with a few mixed pale and dark scales. *Apn* with broad pale scales; *ppn* with some broad- and some narrow-curved pale scales. Following pleural areas each with a patch of broad creamy scales: propleural, subspiracular, postspiracular (continuous with subspiracular scales), paratergite, upper sternopleural, medioposterior sternopleural, and mesepimeral. *Legs:* Fore femur anteriorly dark except for a basal paler area and a ventrobasal pale line, posteriorly broadly pale basally, tapered to a median pale line apically. Mid-femur anteriorly dark, posteriorly white except for a dorsal dark area on the apical half. Hind femur anteriorly white except for a dorsoapical dark marking, posteriorly with the apical two fifths dark. Tibiae all dark. Tarsi all dark, segment I of hind tarsi with a basolateral dull white area. Tarsal claws equal, those on fore and midlegs unidentate, simple on hind legs. *Wings:* Dark. Halter with dark-scaled knob. *Abdomen:* Tergites dark, very narrow basal pale bands on V–VII, large basolateral patches on I–VI (extending to apex of segments on I–III). Sternites white, narrow apical dark bands on some, VII–VIII all dark.

LARVA: Unknown.

BIONOMICS: The type series, all females, were taken while trying to bite the bare legs of native carriers.

DISTRIBUTION: Known only from the type locality.

DISCUSSION: This species has apparently not been retaken since Banks's type series was collected. There are five badly broken female specimens in the U.S.N.M., all of which bear Banks's determination label and which are presumably from the type locality, though not specifically labeled so.

Aedes (Stegomyia) desmotes (Giles)
Figs. 6, 7

1904. *Stegomyia desmotes* Giles, Jour. Trop. Med. 7: 367 (female). Type locality: Philippines. Camp Stotsenberg, Angeles, Pampanga Prov., Luzon (Whitmore). Type: Female (holotype) in B. M.†

1905. *Anisocheleomyia ?albitarsis* Ludlow, Canad. Ent. 37: 131 (female). Type locality: Philippines. Camp Stotsenberg, Angeles, Pampanga Prov., Luzon (Whitmore). Type: Female (holotype) in U.S.N.M.†

1908. *Stegomyia gracilis* Leicester, Cul. Malaya, p. 81 (male, female). Type locality: Malaya. Ulu Klang jungle, Kuala Lumpur (Leicester). Type: Male (holotype) in B. M.†

1910. *Stegomyia albipes* Theobald, Indian Mus., Rec. 4: 11 (female). Type locality: India. Maddathoray, Travancore (Annandale). Type: Female (holotype) in Ind. Mus.

1913. *Stegomyia desmotes* Giles. Edwards, Bul. Ent. Res. 4: 225. Synonymized *gracilis* and *albipes*.

1922. *Aedes* (*Stegomyia*) *desmotes* Giles. Edwards, Indian Jour. Med. Res. 10: 464. Synonymized *albitarsis*.
Barraud, 1934: 225 (adult, larva).

ADULT: A small black and white species. Tibiae each with a white band just before middle. Hind tarsi with basal bands on I–III, IV and V all white.

Male. Wing length approximately 2.0–2.5 mm. *Head:* Proboscis dark. Palpus somewhat longer than proboscis; dark, with basal bands on II–III and small ventrobasal patches on IV–V; slender, a few apical bristles on III–V. Torus with white scales. Vertex broad-scaled, white except for a large subdorsal and a smaller sublateral dark patch; a line of dark upright-forked scales on the nape. *Thorax:* Scutum black-scaled, anterior margin white-scaled, a pair of narrow subdorsal lines of white scales extending from anterior margin halfway to level of wing bases, a large white patch laterally before wing base which continues anteriorly along lateral margin, three short longitudinal pale lines between wing bases, the outer line of these often connecting with the patch before the wing base. No dorsocentral or acrostichal bristles. Scutellar lobes each with a patch of broad white scales. *Apn* with broad white scales; *ppn* with narrow white scales above, broad ones below. Following pleural areas each with a patch of broad white scales: propleural, subspiracular (2), postspiracular, paratergite, prealar, dorsal sternopleural, medioposterior sternopleural, mesepimeral, and meteusternal. *Legs:* Fore femur anteriorly dark except for a basoventral white line; mid-femur anteriorly dark, a white patch before middle, one beyond the middle, and one at apex; hind femur anteriorly white, a dorsal subapical dark marking present which may extend completely across surface to ventral margin. Tibiae dark, a white band on each just before middle, smallest on fore tibia. Fore and mid-tarsi with basal white bands on I–II; hind tarsus with broad basal bands on I–III, IV–V all white (may be a few apical dark scales on IV). Tarsal claws of fore and midlegs unequal, each unidentate; of hind legs equal, simple. *Wings:* Dark. Halter stem white, knob dark-scaled. *Abdomen:* Tergites dark, I with lateral margin white-scaled, II–VII with large basolateral white spots, III–VIII with basodorsal white bands (discontinuous from lateral markings). Sternites dark, with basal white bands. *Terminalia:* Basal lobe of basistyle with two setose lobes. Dististyle with long apical hairs, but without distinct appendage. Paraproct with small ventral arm. Ninth tergite flat medially, with small submedian hairy lobes.

Female. Wing length about 3.0 mm. Similar to male, but differing as follows: Palpus about one fifth as long as proboscis, apex white-scaled. Tarsal claws equal; each unidentate on fore and midlegs, simple on hind legs.

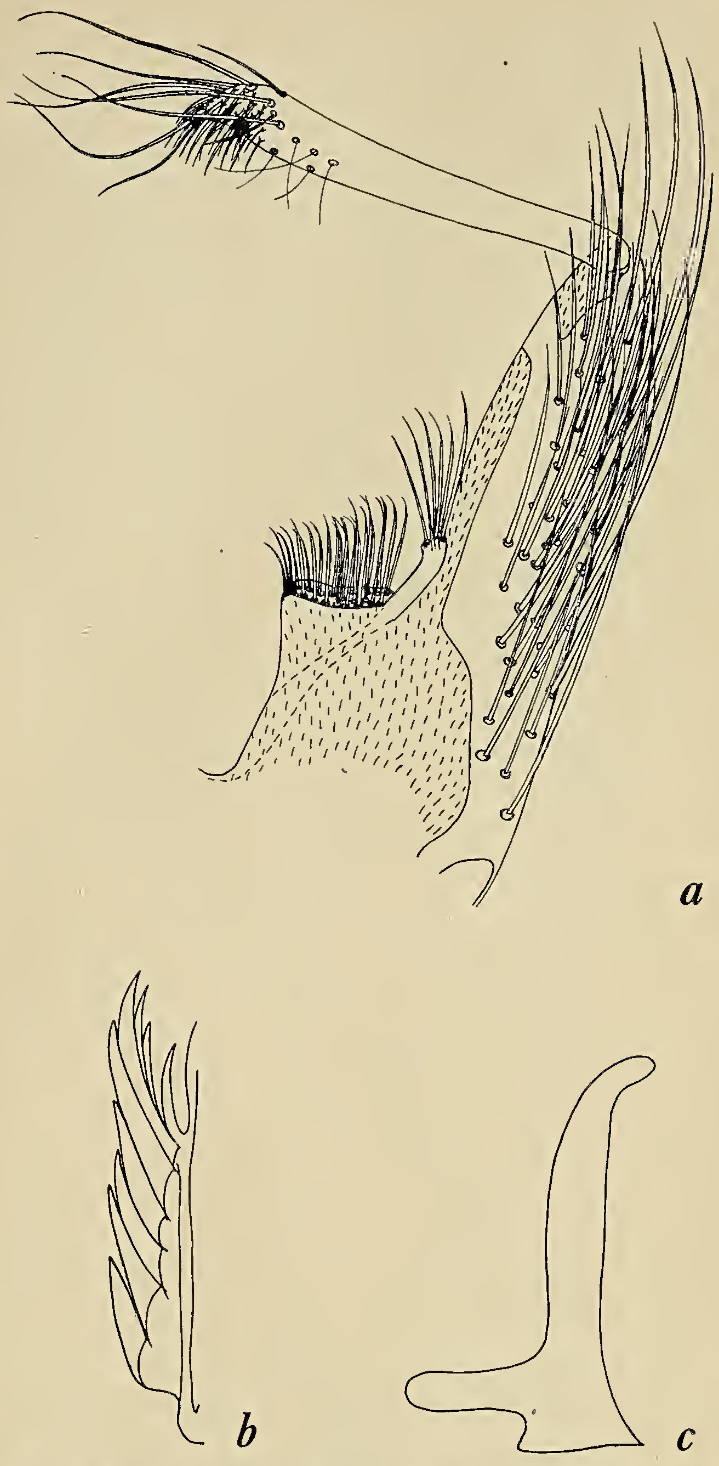

FIG. 6. *A.* (*Stegomyia*) *desmotes.* Male terminalia (Luzon). *a*, Tergal aspect of basistyle; *b*, lateral aspect of paraproct; *c*, dorsal aspect of left half of mesosome.

LARVA: *Head:* Antenna enlarged basally, the rest of the shaft evenly shaped throughout; antennal hair single, small, situated beyond middle. Mouth brushes with comb-like tips. Hair 4 with 7–10 branches; 5, 7, and 8 single; 6 with 2–4; 9 single or double; 12 with 2–3; 13 with 3–6; 14 single or double; 15 with 6–9; 17 with 2–5; 18 with 2–4; 20 single or double. Mentum with 11–13 lateral teeth. *Thorax:* Stellate hairs present. Mesothoracic hairs 9 and 10 single, stout, long; 12 shorter and more slender than 9 or 10; 11 about one fifth as long as 12, more slender. Metathoracic hairs 9–12 similar to the above except that 12 is reduced. An elongate bluntly tipped finger-like projection arises from the tubercle of the 9–12 hair group on the meso- and metathoracic segments, this projection being approximately equal to hair 11 in length. *Abdomen:* Stellate hairs present. Pentad hair 1 with 2–3 branches, occasionally attached to comb plate; 2 and 4 single, 2 may also be attached to comb plate; 3 with 2–4; 5 with 2–3. Comb with 3–5 teeth arranged in a straight line on a pale plate; teeth long, stout, acutely tapered, with fine fringe laterally on attached portion. Siphon pale, no acus, index 1.6–2.5; 2–8 pecten teeth, small with fine denticles at base and occasionally on body of teeth; siphon hair tuft with 3–4 branches. Anal plate incomplete; *lh* with 2–4 branches, no longer than length

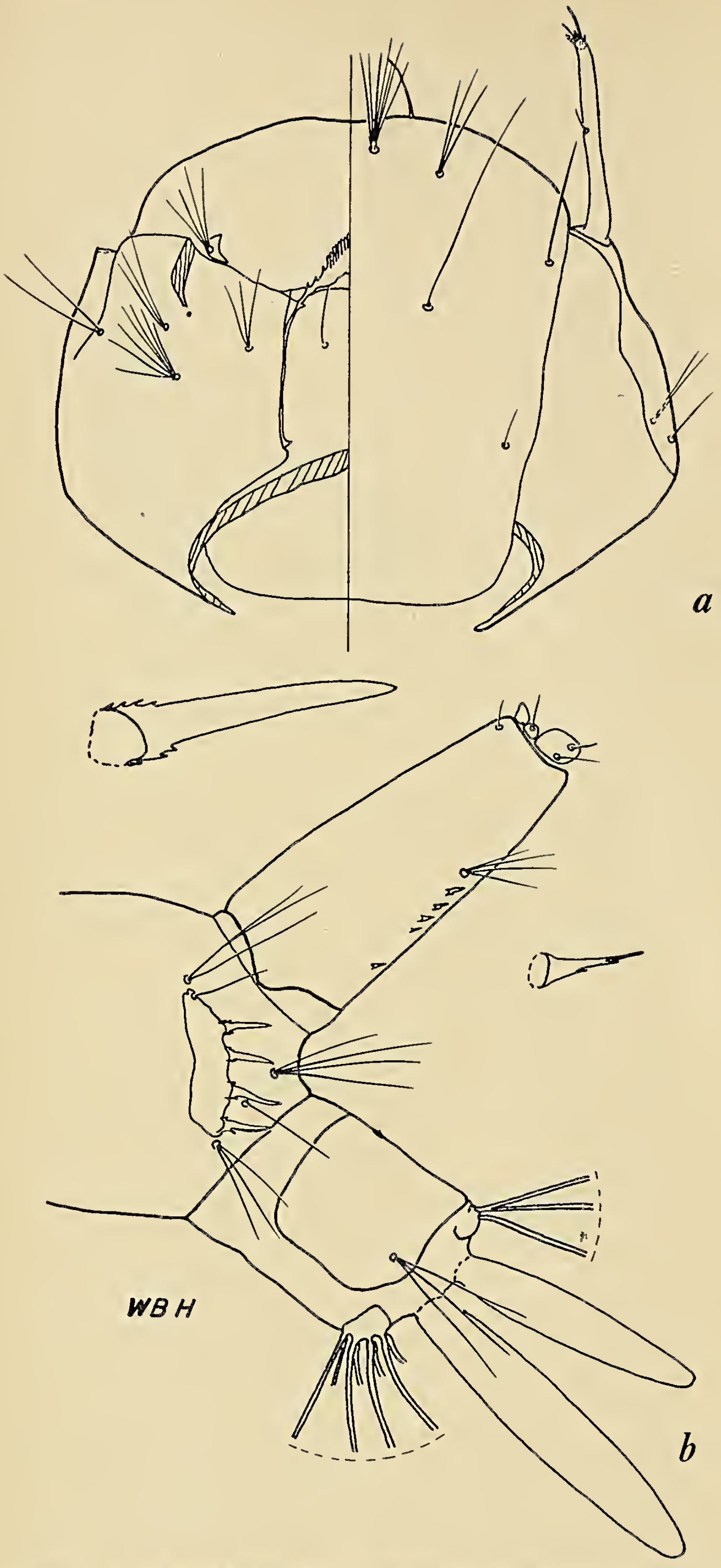

FIG. 7. *A.* (*Stegomyia*) *desmotes.* Larva (Luzon). *a*, Head; *b*, terminal segments. Drawn from exuvium.

of anal plate; *isc* double, *osc* single. Ventral brush of 8 single long hairs, all arising from a barred area; barred area connected to a prominently sclerotized plate on each side. Anal gills slightly tapered, rounded apically, ventral pair 1.3 times longer than the dorsal and 2.0 times longer than the anal plate (gills observed on only one specimen).

BIONOMICS: The adults were found resting in grass on one occasion and hovering about humans on another. The larvae were collected from bamboo stumps.

DISTRIBUTION: *Specimens examined.* R.K.L. Luzon: 1 male, 6 females, 3 sets assoc. skins, Zig Zag Pass and Olongapo, Subic Bay, Zambales Prov. (Rozeboom, MacMillan, Zolick, Zedeck). A.N.S.P. Leyte: Tacloban (Roberts). U.S.N.M. Luzon: 1 male, Los Banos, Laguna Prov.

Outside the Philippines known from India, Assam, Malaya, Cochin China, Borneo, Boeton, and Soemba.

Aedes (Stegomyia) gardnerii (Ludlow)

Fig. 8

1905. *Stegomyia Gardnerii* Ludlow, Canad. Ent. 37: 99 (males, females). Type locality: Philippines. Bulacao, Mindoro (Gardner). Type: 2 males, 3 females (cotypes) in U.S.N.M.† The male with type label in Ludlow's handwriting is here designated lectotype. Terminalia not separated.

1907. *Quasistegomyia gardnerii* Ludlow. Theobald, Mon. Cul. 4: 168. Different combination.

1922. *Aedes* (*Stegomyia*) *gardineri* Ludlow. Edwards, Indian Jour. Med. Res. 10: 464. Lapsus.

Bonne-Wepster and Brug, 1932: 71 (adult).

ADULT: A small black and white species. Posterior scutal scales broad. Hind tarsal segments all basally banded with white (V may be all dark).

Male. Wing length about 2.2 mm. *Head:* Proboscis dark. Palpus slightly longer than the proboscis; basal white bands on II–V, those on II–III incomplete ventrally and on IV–V incomplete dorsally; a few short stiff setae apically on III–V. Torus with broad silvery scales. Vertex all broad-scaled, marked with median, subdorsal, and lateral areas of broad white scales, a line of white scales along the ocular margin; a line of dark upright-forked scales on the nape. *Thorax:* Scutum dark-scaled, marked as follows: white scales along anterior margin, a broad subdorsal band of narrow white scales from the anterior margin to the level of the wing base where it narrows and extends to posterior margin of scutum, a large patch of narrow-curved and broad white scales before the wing base that frequently connects with the subdorsal band, prescutellar area bounded by narrow pale scales, the dark and pale scales along the posterior margin of scutum all broad. No acrostichal or dorsocentral bristles. Scutellum with a patch of broad white scales on each lobe. *Apn* and *ppn* with broad white scales, some narrow dark scales dorsally on *ppn*. The following pleural areas each with a patch of broad white scales: propleural, subspiracular (2 patches present), postspiracular, paratergite, prealar (continuous with the dorsal sternopleural), dorsal sternopleural, medioposterior sternopleural, mesepimeral, and meteusternal. *Legs:* Fore femur anteriorly dark, a basoventral line of white; mid-femur anteriorly with a medial white patch and a white band at the apex; hind femur anteriorly white, marked with a subapical dorsal dark area (may extend across to ventral surface on some specimens); some apical black scales present anteriorly on both hind and mid-femora. Tibiae anteriorly dark. Fore and midtarsi with narrow basal bands on I–II (may be obsolescent on II), hind tarsus with basal bands on I–V, that on IV and V dorsally not more than one half the segment (V may be all dark). Tarsal claws of fore and midlegs unequal, each unidentate; of hind legs equal, simple. *Wings:* Dark-scaled; a small basal white spot may be present on the costa. *Abdomen:* Tergite I with a lateral white band, IV–VI with basal white bands, III may have some mediobasal white scales, disconnected basolateral white spots on II–VII. Sternites with basal white bands. *Terminalia:* Basistyle elongate and slender, sternally greatly swollen on basal half; basal lobe with a prominently setose apex and with a small median mesally directed setose projection.

Female. Wing length 2.2–2.8 mm. Differs from male chiefly as follows: Palpus approximately one fourth as long as the proboscis, apex broadly white. Basal bands on hind tarsal segments IV and V occupying nearly all of the segment dorsally. Tarsal claws equal; each unidentate on fore and midlegs, simple on hind. Tergite II with a few mediobasal white scales, III basally banded.

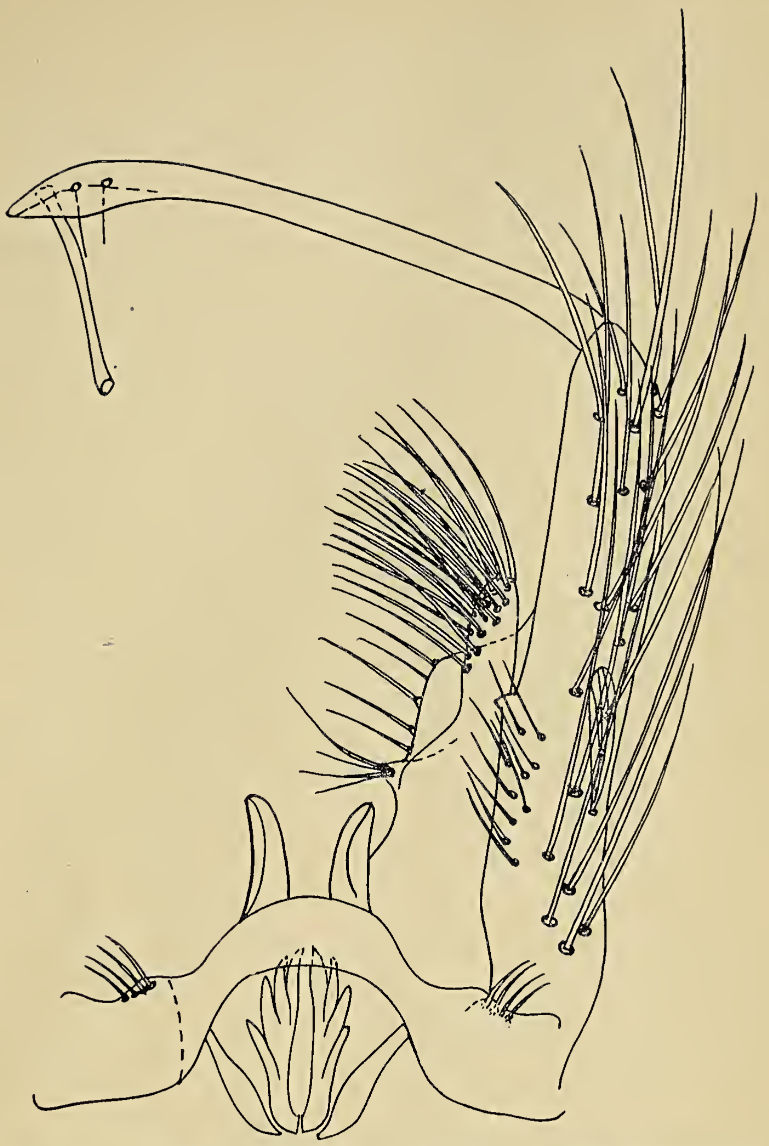

FIG. 8. *A.* (*Stegomyia*) *gardnerii.* Male terminalia (Luzon).

LARVA: *Head:* Antenna smooth, of equal diameter throughout; antennal hair single, small, spine-like, inserted near middle. Mouth brush with comb-like tips. Hair 4 with 9–15 branches; 5 single, occasionally a fine branch or two at base; 6 double, rarely single, stalked; 7 double; 8 and 9 single; 12 with 2–4; 13 single, double on both sides on one specimen, 14 double, rarely single; 15 with 2–4; 17 with 2–5; 18 and 20 with 2–4. Mentum with 7–12 lateral teeth. *Thorax:* Prothoracic hair 1 with 3 branches; 2 single; 3 double. Mesothoracic hair 9 with 2–3 branches, stout, long; 10 and 12 single, stout, long; 11 single or double; a small spine borne on the tubercle. Metathoracic pleural hair group similar to above except that 12 is much reduced. *Abdomen:* Dorsolateral hair on I with 2–5 branches; on II with 2–3. Lateral hair on I single or double; on II with 1–3 branches; on III to V single or double; on VI single. Pentad hair 1 with 2–4 branches; 2 and 4 single; 3 with 3–9; 5 with 3–5. Comb with 5–12 stout teeth in a row, each fringed at base. Siphon without acus, index 2.3–2.9; 8–17 pecten teeth in a row, the teeth with ventral and occasional dorsal denticles; siphon hair tuft with 2–4 branches, length less than width of siphon. Anal plate incomplete; *lh* with 2–3 branches, with a membranous area around point of attachment in anal plate; *isc* double, *osc* single; ventral brush of 8 single hairs (basal hairs occasionally double), with 2–3 off the barred area basally; barred area not connected laterally. Anal gills not clearly discernible in material available; best estimates of length 3.1 and 4.2 times longer than anal plate.

The larva of *gardnerii* is nearly identical with those of *scutellaris*, *albopictus*, and *paullusi*, differing only as given in the larval key.

BIONOMICS: Adults were collected hovering about humans and resting in woods and in nipa-palm areas. Larvae were collected on several occasions from bamboos and once from a hollow palm stump.

DISTRIBUTION: *Specimens examined.* R.K.L. Luzon: 7 males, 18 females, 1 larva, 20 sets assoc. skins, Olongapo, Zambales Prov. (Zolick, McMillan, Rozeboom). Mindanao: 2 males, 2 females, 1 larva, 1 set assoc. skins, Mercedes and Zamboanga (Laffoon, Johnson). Palawan: 1 male, Irahuan River (Johnson, Laffoon); 1 larva, Tacburos (Johnson). Culion: 1 male, 1 female, 2 larvae, Pilapil (Johnson, Laffoon). C.A.S. Mindoro: San Jose (Ross). A.N.S.P. Leyte: Tacloban (Roberts). C.C. Luzon: 3 males, 2 females, Agoo, LaUnion Prov. (Franclemont). U.S.N.M. Luzon: 1 male, Batangas, Batangas Prov.; 2 males, 1 female, Los Banos, Laguna Prov.; 1 male, 2 females, Pangpang, Sorsogon Prov. (Cowell, Ingal); 2 males, 4 larvae, Balibago (Cowell, Ingal).

Literature records. Luzon: Los Banos and Angeles, Laguna Prov. Mindanao: Parang. Jolo. (Bohart, 1945: 62.)

Unknown outside the Philippines.

DISCUSSION: This species is closely related to *w-albus* (Theobald), which is rather widely distributed in the Oriental Region outside the Philippines. The male terminalia of the two species are apparently identical. The female of *w-albus* differs from *gardnerii* in having the white sublateral bands of the scutum broadly connected anteriorly and the fifth hind tarsal segment all dark. However, from the meager amount of material of *w-albus* that has been described in the literature, it is apparent that considerable variation in scutal and tarsal markings occurs; and it is quite possible that once the extent of this variation is known, these two species will prove to be similar, or at the most subspecies.

A Philippine female specimen of *gardnerii* was compared to the type (female) of *imitator* Leicester (a synonym of *w-albus* from Malaya) and was found to differ from it in the manner described above for *w-albus*. The larva of *w-albus* is undescribed.

Aedes (Stegomyia) meronephada (Dyar and Shannon)

Fig. 9

1925. *Catatassomyia meronephada* Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 71 (16 females). Type locality: Philippines. Mt. Makilling, 1,500–2,000 ft. alt., Los Banos, Laguna Prov., Luzon (F. X. Williams). Type: 15 females (cotypes) in the U.S.N.M.† The specimen bearing the Mt. Makilling label is here designated lectotype.

ADULT: Scutum marked with an obovate anteromedian area of silvery scales. Hind tarsal segments I and II basally banded, III all white or nearly so, IV and V dark.

Male. Unknown.

Female. Wing length about 2.5–3.0 mm.

Head: Proboscis dark. Palpus about one sixth as long as the proboscis, dark. Torus with broad silvery scales mesally. Vertex broad-scaled, marked with a longitudinal median area and an ocular line of silvery scales and with a lateral pale patch; a line of yellow or brown upright-forked scales on the nape. *Thorax:* Integument ochreous. Scutum with small narrow dark-brown scales, marked with an obovate median patch of narrow silvery scales that begins at the anterior margin and extends posteriorly to about the level of the paratergite. No acrostichal bristles and only a few dorsocentrals. Scutellar mid-lobe with broad silvery scales, some of the apical scales black; lateral lobes with broad dark scales. *Apn* with narrow-curved silvery scales; *ppn* bare. Following pleural areas each with a patch of broad silvery scales: propleural, subspiracular, paratergite, dorsal sternopleural, medioposterior sternopleural, and mesepimeral. *Legs:* Fore and mid-femora dark anteriorly, apical white scales on the latter; hind femur anteriorly with basal three fifths and apex white, remainder dark. Tibiae dark. Fore and mid-tarsi dark, a small basal white patch on I; hind tarsal segments I–II with broad basal white bands, III all white or with as much as apical fifth dark, IV and V dark. *Wings:* Dark-scaled. Halter knob dark-scaled. *Abdomen:* Tergites dark, lateral margin of I silver-scaled, basolateral silvery patches present on II–VII. Sternites with basal white bands.

LARVA (description based on four specimens from Osmena, Samar): *Head:* A rounded prominence at eye margin. Antenna smooth, of equal diameter throughout; antennal hair double, inserted medially, reaching just beyond tip of antenna. Hair 4 fan-shaped, with 7–11 branches; 5 single; 6 double, branches equal, parallel; 7 with 5–8; 8 single or double; 9 with 2–4; 12 with 6–9; 13 single; 14 very small, single or double; 15 developed as a strong horn-shaped projection; 17 double or triple, very small and not always seen; 18 stalked, with 4–6; 20 with 2–4. Mentum with 7–8 lateral teeth. *Thorax:* Prothoracic hair 1 double, one branch about one third longer than the other; 2 single; 3 with 19–22 branches. Mesothoracic hair 9 with 12–16 branches; 10 and 12 long, stout, single; 11 not seen; a sharp spine also borne on the 9–12 group tubercle. Metathoracic hair 9 with 5–9 branches; 10 long, stout, single; 12 single, much reduced; 11 not seen; a sharp spine also present on the tubercle. *Abdomen:* Dorsolateral hair on I with 5–8 branches; on II with 6–8. Lateral hair on I single; on II with 4–7 branches; on III, IV, and VI with 4–5; on V with 3–4. Pentad hair 1 with 9–13 branches; 2 and 4 single; 3 with 2–3; 5 with 2–4. Comb with 18–24 long teeth in a row, a partial uneven second row of small teeth just anterior to large comb teeth; each tooth with a fine lateral fringe extending nearly to apex. Siphon

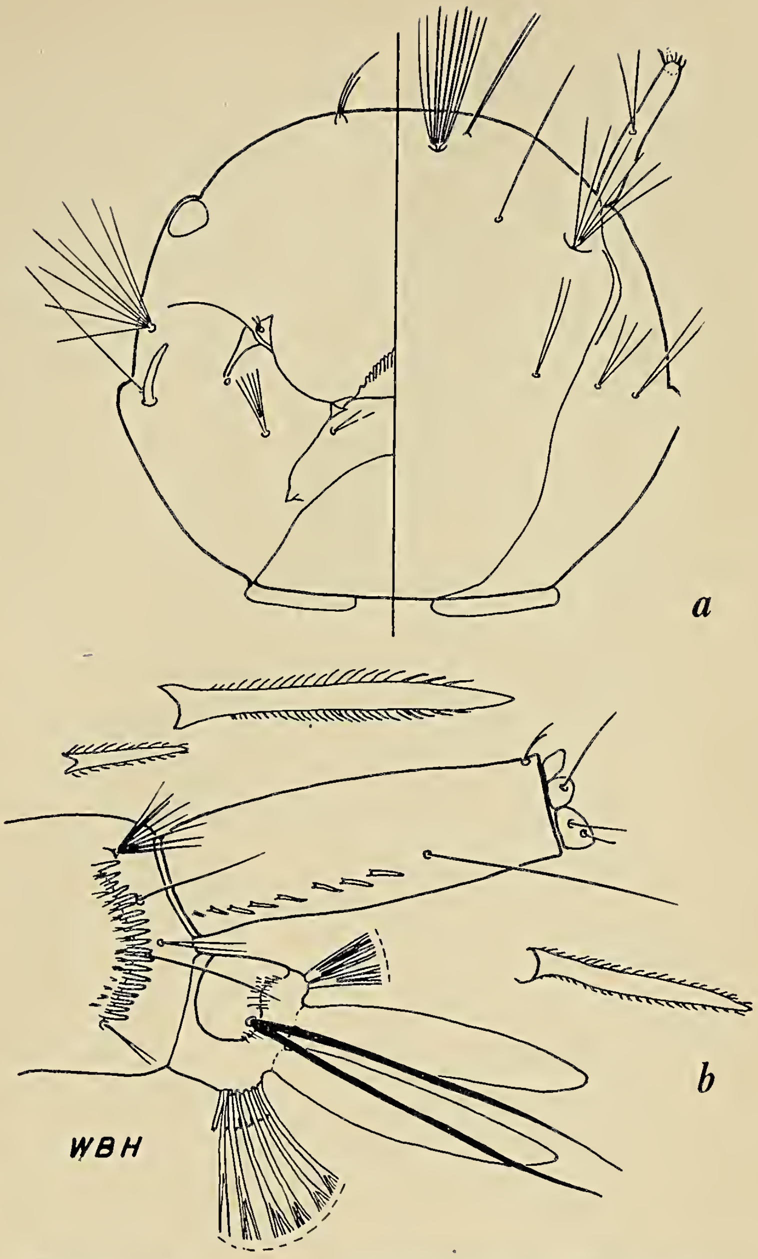

FIG. 9. *A.* (*Stegomyia*) *meronephada.* Larva (Samar). *a*, Head; *b*, terminal segments.

pilose, without acus, index 2.7–3.4; 7–11 smooth pecten teeth; siphon hair long, single (3-branched at three fifths of length in one specimen) extending beyond tip of siphon. Anal plate incomplete, with a patch of small spines along the posterior lateral margin; *lh* of two long, stout, equal branches borne on a tubercle; *isc* with 3 branches, *osc* with 2 or 3; ventral brush with 12 stalked tufts, each with 2–4 branches, barred area absent. Gills rather narrow, subequal, the dorsal pair (two specimens) 3.7–4.2 times longer than the anal plate.

BIONOMICS: Females were collected on one occasion resting at the base of trees in wet jungle at about 1,000 feet elevation. The larvae were collected once from the axils of a banana-like plant along a jungle stream at about 800 feet elevation. The axil spaces were small and held a very small amount of water.

DISTRIBUTION: *Specimens examined.* R.K.L. Samar: 1 female, 1 set assoc. skins, 5 larvae, Osmena, about 800 feet (Laffoon, Knight). Leyte: 3 females, Mt. Lobi, nr. Dagami (Laffoon, Knight). A.N.S.P. Leyte: Mt. Lobi, about 1,000 feet. Burugwan River, Tacloban (Roberts).

Unknown outside the Philippines.

Aedes (Stegomyia) albopictus (Skuse)

Fig. 10

1894. *Culex albopictus* Skuse, Indian Mus., Notes 3: 20 (3 females). Type locality: India. Calcutta, Bengal (Cotes). Type: Female (holotype) in University of Sydney, N. S. W. Edwards (1932: 164) indicates that this description was actually published in 1895.

1901. *Stegomyia scutellaris.* Walker. Theobald, Mon. Cul. 1: 298. Also: Banks, Philippine Jour. Sci. 3: 246. 1908. Leicester, Cul. Malaya, p. 86. 1908. Misidentifications.

1903. *S. scutellaris* subspecies *samarensis* Ludlow, Jour. N. Y. Ent. Soc. 11: 138 (males, females). Type locality: Philippines. Samar. Type: 2 males, 4 females (cotypes) in U.S.N.M.†

1904. *Stegomyia Lamberti* Ventrillon, Paris Mus., Bul. 10: 552 (males, females). Type locality: Madagascar. Majunga, Tananarive (Lambert). Type: Location unknown. Not found in Paris Museum by J. A. Reid in 1946.

1910. *Stegomyia nigritia* Ludlow, Canad. Ent. 13: 194 (2 females). Type locality: Philippines. Cotabato, Cotabato Prov., Mindanao. Type: 2 females (cotypes) in U.S. N.M.†

1911. *Stegomyia quasinigritia* Ludlow, Psyche 18: 129 (male). Type locality: Philippines. Turucan, Mindanao (Seith). Type: Male (holotype) in U.S.N.M.†

1917. *Aedes* (*Stegomyia*) *albopicta* Skuse. Edwards, Bul. Ent. Res. 7: 209. Synonymized *samarensis.*

1925. *Aëdes* (*Stegomyia*) *albopictus* Skuse. Dyar and Shannon, Insecutor Inscitiae Menstruus 13: 74. Synonymized *nigritia* and *quasinigritia.*

1932. *A.* (*S.*) *albopictus* Skuse. Edwards, Genera Insectorum, fasc. 194, p. 164. Synonymized *lamberti.*

Barraud, 1934: 233 (description, systematics). Bonne-Wepster and Brug, 1932: 73 (complete treatment). Bohart and Ingram, 1946: 5, 35, 64 (description, systematics, biology).

ADULT: A black and white species, with a prominent median longitudinal silvery scutal stripe and basal abdominal bands. Hind tarsal segments I–IV basally banded, V all white.

Male. Wing length 2.0–2.5 mm. *Head:* Proboscis dark. Palpus slightly longer than proboscis; dark, segments II–V with basal white bands, those on II–III incomplete ventrally and those on IV–V incomplete dorsally; a few short stiff setae apically on III–V and along IV. Torus with silver scales. Vertex broad-scaled; marked with median, sublateral, and lateral areas of white scaling; dark upright-forked scales along the nape. *Thorax:* Scutum covered with narrow dark scales, marked with a median stripe of narrow silvery scales which narrows posteriorly and forks at the prescutellar space, a posterior submedian silvery line, and a patch of broadened and narrow silvery scales over the wing base. Dorsocentral bristles present, acrostichal bristles absent. Scutellum with a patch of broad silvery scales on each lobe, the mid-lobe with a few black scales at the apex. *apn* and *ppn* with broad silvery scales, some narrow dark scales dorsally on *ppn*. The following pleural areas each with a patch of broad silvery scales: propleural, subspiracular, paratergite, dorsal sternopleural, medioposterior sternopleural, and mesepimeral (this patch covering the base of the mesepimeral hair tuft and approximately V-shaped), the scale patches not forming sharply defined lateral bands. *Legs:* Femoral knee-spots present, hind femur largely white-scaled anteriorly. Tibiae dark anteriorly. Fore and midtarsi with segments I and II basally banded, hind tarsus with basal white bands on I–IV, V all white. Tarsal claws of fore and midlegs unequal, the larger claw unidentate, the smaller simple; claws of hind legs equal, simple. *Wings:* Dark-scaled, a small basal spot of silver scales on the costa. *Abdomen:* Abdominal tergites with narrow (sometimes incomplete) basal bands which widen into spots sublaterally, detached oblique lateral spots also present. Sternites with basal white bands. *Terminalia:* Basistyle with prominent, setose basal lobe (arising medially). Ninth tergite produced medially into a distal blunt projection.

Female. Wing length about 3.0 mm. Palpus approximately one fifth as long as the proboscis, apical half white-scaled. Tarsal claws equal, simple.

LARVA (as in Fig. 13): Description from adult-associated larval skins. *Head:* Antenna smooth, evenly shaped throughout; antennal hair single, small, inserted medially. Mouth brush with comb-like tips. Hair 4 with 8–13 branches; 5, 8, 9, and 14 single; 6 and 13 single or double; 7 with 2–3; 12 with 2–5; 15 with 2, rarely 3 or 4; 17 with 2–5; 18 with 1–3; 20 single or double. Mentum with 10–12 lateral teeth. *Thorax:* Stellate hairs present. Prothoracic hair 1 with 2–3 branches; 2 single; 3 double. Mesothoracic hair 9 double, rarely with 3 branches; 10 and 12 single, long, stout; 11 single, short. Metathoracic pleural hair group similar to above except that 12 is reduced. *Abdomen:* Stellate hairs present. Dorsolateral hairs on I and II with 2–3 branches. Lateral hair on I single; on II single or double; on III to V with 2–3 branches; on VI single or double. Pentad hair 1 with 2–3 branches; 2 and 4 single; 3 with 3–6; 5 with 2–3. Comb with 8–12 strong teeth, with denticles or fringes laterally on attached portion which may extend part way onto shaft. Siphon smooth, without acus, index about 2.0; siphon hair tuft with 2–3 branches, inserted near middle of siphon; 8–12 pecten teeth with ventral and occasionally dorsal denticles. Anal plate smooth, narrowly incomplete; *lh* with 2 unequal branches; *isc* double, *osc* single; ventral brush of 8 single hairs borne on a barred area; barred

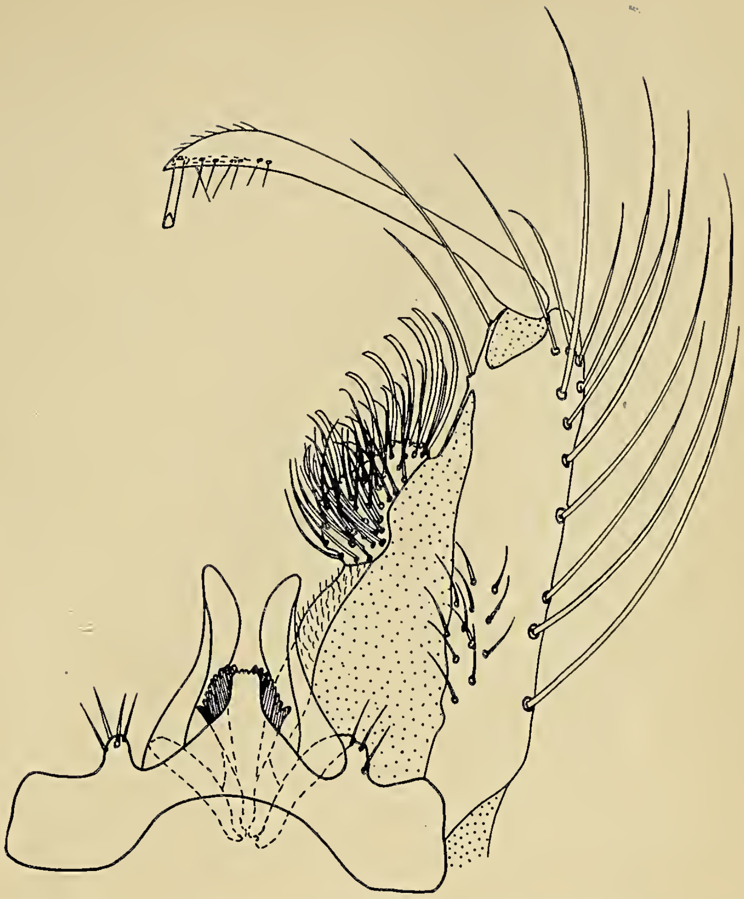

FIG. 10. *A.* (*Stegomyia*) *albopictus*. Male terminalia (Palawan).

area not connected laterally. Anal gills sausage-shaped, subequal, 2.0–4.5 times longer than anal plate.

Indistinguishable from *scutellaris* and *paullusi.*

BIONOMICS: Approximately 65 larval collections and numerous adult catches were made of this species in various portions of the Philippines. The larvae were commonly found in all types of artificial containers, even within occupied homes. Nearly as common were such natural containers as opened coconut shells and husks, fallen palm fronds, and sections of split bamboos. Less commonly, larvae were found in various types of tree holes and in cut bamboos. The adults were encountered everywhere in the vicinity of human habitations and would try to bite throughout the day under a variety of conditions.

DISTRIBUTION: *Specimens examined.* R.K.L. Luzon: Subic Bay, Zambales Prov. Leyte: Baybay; Tacloban. Samar: Osmena; Pintanahon; Ducong (on Basey River); Bulusao. Palawan: Tacburos; Puerto Princesa; Irahuan River; Iwahig Penal Colony. Culion: Pilapil. Balabac: Cape Melville. Busuanga: Coron. Mindanao: Zamboanga, City of Zamboanga Prov.; San Ramon, City of Zamboanga Prov.; Mercedes, Zamboanga Prov. Jolo: Jolo. C.C. Luzon: Agoo, LaUnion Prov.; Tayug, Pangasinan Prov. (Franclemont). C.A.S. Mindoro: San Jose (Ross). Leyte: Carigara; Tunga; Tacloban (Ross).

Literature records. Luzon: Banahao (Edwards, 1929*a*: 5). Leyte: Tolosa (Bick, 1949: 2). Panay. Negros. Guimaras. (Bohart, 1945: 61.)

Outside the Philippines this species is known from the Ethiopian Region and throughout the Oriental Region, and now occurs also in Saipan, Tinian, and Hawaii of the Australasian Region. The other records from the Australasian Region apparently refer to one or more of the *scutellaris* complex.

Aedes (Stegomyia) paullusi
Stone and Farner
Fig. 11

1945. *Aedes* (*Stegomyia*) *paullusi* Stone and Farner, Biol. Soc. Wash., Proc. 58: 155 (males, females). Type locality: Philippines. San Antonio, Samar (Paullus). Type: Male (holotype) in U.S.N.M.†

ADULT: A black and white species, marked with a prominent median longitudinal white scutal band and two distinct longitudinal pleural bands. Hind tarsal segments I–IV basally banded, V all white.

Male. Wing length about 2.2–2.5 mm. *Head:* Proboscis dark except for a stripe of pale scales extending almost entire length of ventral surface. Palpus approximately equal to proboscis in length; dark, with basal white bands on II–III and ventrobasal white patches on IV–V; a few short stiff setae apically on III–V. Torus ringed with white scaling. Vertex broad-scaled, a large subdorsal dark patch and a smaller lateral dark area, remainder white; dark upright-forked scales on the nape. *Thorax:* Scutum with narrow brown scales, marked as follows: A median white stripe from the anterior margin that narrows posteriorly and is faintly forked in the prescutellar area, an indistinct posterior submedian line of narrow yellowish scales, a patch of broad white scales over wing base, and a line of white scales along the anterolateral margin. Scutellum with broad white scales on all three lobes, a few dark scales apically on midlobe. *Apn* with broad white scales, *ppn* with some narrow-curved dark scales dorsally and an elongated patch of broad white scales below. Following pleural areas each with a patch of broad white scales: Propleural, dorsal sternopleural, ventroposterior sternopleural, paratergite, and mesepimeral (V-shaped). The white scale patches on *apn*, *ppn*, paratergite, and on the scutum over the wing base combine to form a sharply demarcated longitudinal white band; the white scale patches on propleuron, dorsal sternopleuron, and mesepimeron (the dorsal arm of the V) form a second sharp longitudinal white band of scales ventral to the first. *Legs:* Fore femur dark anteriorly, marked with a somewhat interrupted white line on ventral surface and an apical patch of white scales; mid-femur anteriorly with a distinct median line of white scales which is separated from the apical white patch by dark scales; hind femur anteriorly with a broad white longitudinal stripe, this stripe widest at base and only slightly interrupted from apical white patch. Tibiae dark. Fore and mid-tarsi with a basal white patch on segments I–II; hind tarsal segments I–IV with basal white bands, V all white, the band on I occupying from one-fourth to one-third length of segment and interrupted on inner surface, on II about one third, on III about one half, on IV about two thirds or more. Tarsal claws of fore and midlegs unequal, each unidentate; of hind legs equal, simple. *Wings:* Dark, a small patch of white scales basally on costa. Halter knob dark-scaled. *Abdomen:* Tergite I with lateral margin white-scaled; II–VI with subbasal (more noticeable on posterior segments) narrow white bands, these turning abruptly caudad at dorsolateral margin and there ending near the large oblique dorsolateral spots (attached to these spots on at least one segment), the band on II interrupted; tergite VII, and sometimes VI, with the band broken on either side of a median patch. Sternites II–VI with basal white bands. *Terminalia:* Basal lobe of basistyle truncate, with a ventro-apical area of well-developed setae.

Female: Wing length 3.0–3.7 mm. Similar to male. Palpus about one-fifth length of proboscis, with large white patch on dorsal side of apical segment. Line of white scales on front femur absent or poorly developed. Tarsal claws equal, simple.

LARVA (as in Fig. 13): Description from adult-associated larval skins. *Head:* Antenna smooth, evenly shaped throughout; antennal hair single, short, inserted medially. Mouth brushes with comb-like tips. Hair 4 with 8–11 branches; 5, 6, 8, 9, and 14 single; 7 with 2–3; 12 with 2–5; 13 single or double; 15 double; 17 with 2–7; 18 with 3–6; 20 with 2, rarely 1–5. Mentum with 10–13 lateral teeth. *Thorax:* Prothoracic hair 1 with 2–3 branches; 2 single; 3 double. Mesothoracic hair 9 with 2–3 branches; 10 and 12 single, stout, long; 11 single, small. Metathoracic pleural hair group similar to above, except that 12 is reduced. *Abdomen:* Dorsolateral hair on I with 3–4 branches; on II with 2–3. Lateral hair on I single; on II and III with 2–3 branches; on IV and V double; on VI single or double. Pentad hair 1 with 3–6 branches; 2 and 4 single; 3 and 5 with 3–7. Comb with 8–10 strong teeth in a row, each tooth with a lateral fringe on attached portion and extending onto shaft. Siphon smooth, without acus, index about 2.0; siphon hair tuft with 2–4 branches, inserted near middle of siphon; 9–17 pecten teeth each with 1 large and occasionally 1 or 2 very small ventral denticles. Anal plate narrowly incomplete, with a small area of spicules along the posterior median

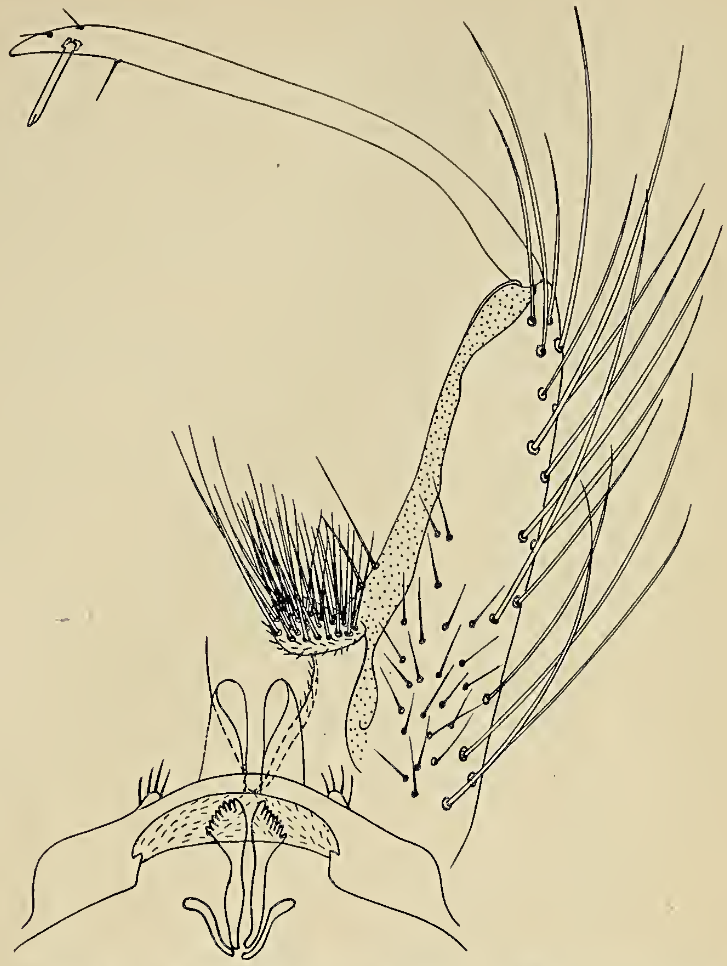

FIG. 11. *A.* (*Stegomyia*) *paullusi.* Male terminalia (Jolo).

margin; *lh* with 2 branches, rarely 1 or 3, equal or unequal in length; *isc* with 2–4, *osc* single; ventral brush of 8 single hairs borne on a barred area; barred area not connected laterally. Anal gills sausage-shaped, dorsal pair 2.5 times as long as anal plate and 1.2 times as long as ventral pair.

Indistinguishable from *albopictus* and *scutellaris.*

BIONOMICS: Adults were collected on several occasions hovering about humans in the woods. Numerous larval collections were made, being most commonly found in rock pools in drying stream beds. Other collections were from coconut husks, coconut shells, fallen coconut fronds, rot holes on fallen logs, a hollow on a palm trunk, and bamboos.

DISTRIBUTION: *Specimens examined.* R.K.L. Leyte: Dagami Mts., 1,000 ft. alt.; Tacloban. Samar: Osmena; Macarata; Pintanahon; Ducong; Shohoton Springs; Bulusao. Palawan: Irahuan River. Mindanao: San Ramon, City of Zamboanga Prov.; Zamboanga, City of Zamboanga Prov.; Mercedes, Zamboanga Prov. Jolo: Jolo. C.A.S. Leyte: Carigara; Santa Rosa; Tacloban (Ross).

Literature records. Calicoan: N'goles; Baras. Samar: San Antonio. Leyte: Abuyog. (Stone and Farner, 1945: 156.)

Outside the Philippines known from Taroena, Sangir Islands; Celebes; Ceram; Ambon; Sanana; and Sumatra (Brug and Bonne-Wepster, 1947: 10).

Aedes (Stegomyia) scutellaris (Walker)

Figs. 12, 13

1858. *Culex variegatus* Doleschall (nec Schrank, 1781), Nat. Tijdschr. Nederland. Indië 17: 77 (female?). Type locality: Netherlands East Indies. Amboina. Type: Nonexistent, formerly in Vienna Museum (according to Barraud, 1934: 240).

1859. *Culex scutellaris* Walker, Linn. Soc. London, Proc. 3: 77 (male). Type locality: Aru (Aroe) Islands (Wallace). Type: Female (holotype) in B.M.† Original description did not mention female.

1861. *Culex zonatipes* Walker, Linn. Soc. London, Proc. 5: 229 (male). Type locality: New Guinea. Dorey. Dutch New Guinea (Wallace). Type: Female (holotype) in B.M.† Identified as type by Waterhouse. Original description did not mention female.

1926. *A. variegatus* var. *hebrideus* Edwards, Bul. Ent. Res. 17: 102 (male, female). Type locality: New Hebrides. Hog Harbor, Espiritu Santo (Buxton). Type: Male (holotype) in B.M.† Terminalia separated.

Stone, 1947: 85 (systematics). Stone and Farner, 1945: 159 (adult key). Barraud, 1934: 240 (adult, larva). Farner and Bohart, 1944: 37 (adult, systematics). Forbes and Horsfall, 1946: 602 (bionomics). Penn, 1947: 43 (bionomics).

ADULT: Similar to *paullusi*, differing as follows: Proboscis dark. Scutum lacking the line of white scales on the anterolateral margin. Mid-femur with a broken ventral line of white scaling anteriorly but entirely lacking the median longitudinal line. Tergal bands more widely separated from base of segments, being from one fourth to two fifths the width of the segment removed. Male terminalia similar except that the basal lobe of basistyle is of a different form.

LARVA (as in Fig. 13): Description from adult-associated larval skins. *Head:* Antenna smooth, evenly shaped throughout; antennal hair single, short, inserted medially. Mouth brush with comb-like tips. Hair 4 with 8–12 branches; 5, 6, 8, 9, 13, and 14 single; 7 with 2, rarely 1–3; 12 with 3, rarely 2; 15 single or double; 17 with 2–4, usually 3; 18 single or double; 20 single or double. Mentum with 11–12 lateral teeth. *Thorax:* Prothoracic hair 1 with 2–3 branches; 2 single; 3 double, rarely single. Mesothoracic hair 9 with 2–3 branches; 10 and 12 single, long, stout; 11 single, small. Metathoracic hair 9 double; 10 and 11 similar to those on mesothorax; 12

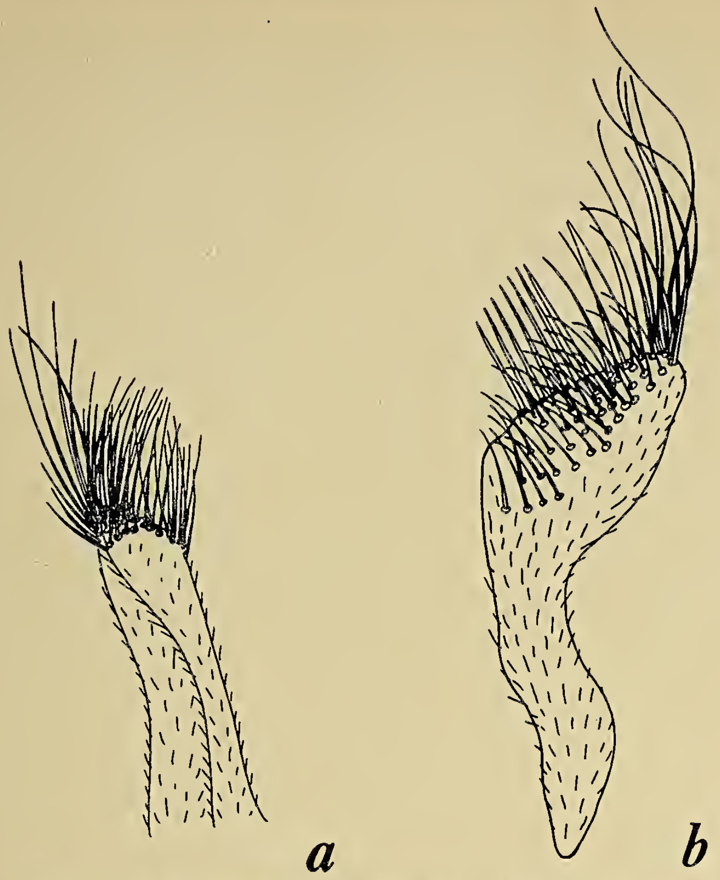

FIG. 12. *A.* (*Stegomyia*) *scutellaris*. Male terminalia. *a*, Tergal aspect of right basal lobe of basistyle (Luzon); *b*, lateral aspect of left basal lobe of basistyle (Mindanao).

much reduced. *Abdomen:* Dorsolateral hair on I with 3–4 branches, usually 3; on II with 2–3. Lateral hair on I single; on II–V double; on VI single. Pentad hairs 1 and 5 with 3–4 branches; 3 with 3–6; 2 and 4 single. Comb with 9–15 strong teeth in a row, each tooth with lateral fringe or denticles on attached portion which may extend onto basal one third of shaft. Siphon smooth, without acus, index 1.8–2.8; 9–15 pecten teeth with strong ventral denticles; siphon hair tuft with 3–4 branches. Anal plate incomplete; a few spicules along posterior median margin; *lh* with 2 unequal branches; *isc* double, rarely 1–3; ventral brush of 8 single hairs (occasionally double), borne on a barred area; barred area not connected laterally. Anal gills nearly subequal, dorsal pair about 3 to 5 times longer than anal plate.

Indistinguishable from *albopictus* and *paullusi*.

BIONOMICS: Adults were encountered hovering about humans in shaded areas in the vicinity of native habitations. Larval collections (10) were made from tin cans and similar containers; coconut shells, husks, and fallen fronds; tree holes and rot holes on fallen logs; and in a piece of split bamboo.

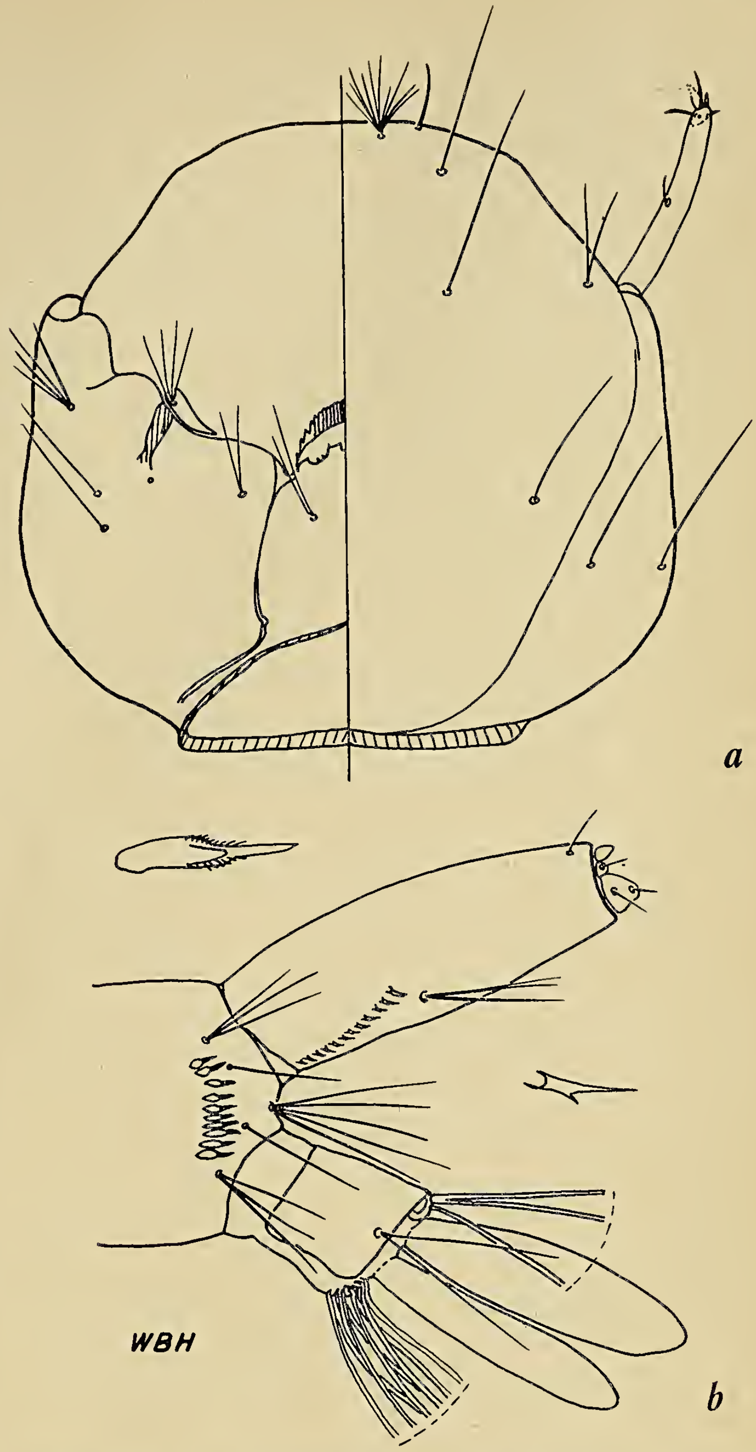

FIG. 13. *A.* (*Stegomyia*) *scutellaris* subgroup. Larva. *a*, Head; *b*, terminal segments.

DISTRIBUTION: *Specimens examined.* R.K.L. Luzon: Olongapo, Subic Bay, Zambales Prov. (Zolick). Leyte: Tacloban (Roberts, Knight). Samar: Pintanahon (McMillan). Palawan: Irahuan River (Johnson, Laffoon, Fitzgerald); Tacburos (Laffoon). Mindanao: Zamboanga, City of Zamboanga Prov. (Johnson, Laffoon, Knight). C. C. Luzon: Agoo, LaUnion Prov. (Franclemont). C.A.S. Mindoro: San Jose (Ross).

Literature records. Luzon: Los Banos, Laguna Prov.; Camp Stotsenberg, Pampanga Prov. (Bohart, 1945: 62). Calicoan (Stone and Farner, 1945: 158).

Outside of the Philippines, this species is known from New Hebrides, Rennell and Bellona Islands, New Guinea, Sumatra, Aru, Amboina, Moluccas, Celebes, Ceram, Palau Islands, Andamans, and from several other small islands in the Dutch East Indies.

DISCUSSION: The type female of *scutellaris* has been examined by the senior author and found to be quite moldy; in addition, it is lacking all of both fore tarsi, segments II–V of the mid-tarsi, and segments III–V of the hind tarsi. Because of the absence of most of the tarsal segments, it was not possible to key this specimen beyond couplet 4 of Stone and Farner's (1945: 159) key to the adults of the *scutellaris* subgroup. However, it does differ rather markedly from *hebrideus* as defined in that key (and from *scutellaris* as described above for the Philippines) in tergal markings. The dorsum of the tergites is dark except for a single subbasal row of white scales on VI, a nearly complete subbasal row on V, and a short mesal extension of the subbasal lateral white stripe onto the dorsum on II–V and on VII. Nonetheless, there seems little doubt that the species formerly called *hebrideus* is actually true *scutellaris*, since Stone (1947: 85) has examined the terminalia of a topotypic male of *scutellaris* and found it to be identical with terminalia of specimens from the New Hebrides, New Guinea, and the Philippines.

The single female type specimen of *zonatipes* has been examined and found to be in very poor condition. The scutum, pleurae, and abdominal tergites are almost completely bare of scales and the mid-tarsi are missing. However, it was possible to key it to couplet 10 of Stone and Farner's (1945: 160) key, which takes it to either *pseudoscutellaris* or *hebrideus*. The rubbed condition of the tergites precludes further identification.

The male type of *hebrideus* was studied and was found to go satisfactorily to *hebrideus* in Stone and Farner's (1945: 160) key. The only pertinent difference noted between this specimen and the type of *scutellaris* was the more complete condition of the abdominal bands, being as described in this paper for Philippine *scutellaris*.

Aedes (Stegomyia) mediopunctatus var. perplexus (Leicester)

Figs. 14, 15

1908. *Stegomyia Perplexa* Leicester, Cul. Malaya, p. 83 (male, female). Type locality: Malaya. Kuala Lumpur and The Gap (Leicester). Type: Male, female (cotypes) in B.M.†

ADULT: A black and white species, marked with a prominent median longitudinal white scutal band. Hind tarsal segments I–II basally banded, III all dark, IV–V all white.

Male. Wing length about 2.6 mm. Proboscis dark, often with some ventral white scaling. Palpus approximately equal to the proboscis in length; segments II–V with basal white bands, those on IV–V dorsally incomplete; a few short stiff setae apically on III–V. Torus with nearly complete ring of silvery scales. Vertex with broad white scales, marked by a large subdorsal area and a smaller sublateral patch of broad dark scales; a line of dark upright-forked scales on nape. *Thorax:* Scutum dark-scaled, with white markings as follows: a broad median longitudinal band tapering from anterior margin to the prescutellar space and then continued to posterior scutal margin, and a large patch of broad white scales over and before the wing base. Scutellar mid-lobe with broad white scales, lateral lobes with broad dark scales (occasionally a few broad white scales here). *Apn* and *ppn* with broad white scales. Following pleural areas each with a patch of broad white scales: propleural, subspiracular, postspiracular, paratergite, dorsal sternopleural, medioposterior sternopleural, and mesepimeral. *Legs:* Fore femur anteriorly dark except for a ventrobasal white line; mid-femur anteriorly dark except for a ventral white line and an apical white patch; hind femur anteriorly white, with an apicodorsal dark area that extends narrowly across the anterior surface subapically. Tibiae dark, a ventrobasal white area present on fore and hind. Fore and mid-tarsi dark except for a basal band on I, may be a few basal pale scales on II; hind tarsus with broad basal bands on I–II, III all dark, IV–V all white. Tarsal claws of fore and midlegs unequal, each unidentate; of hind legs equal, simple. *Wings:* Dark-scaled, a small basal patch on the costa. Halter knob dark-scaled. *Abdomen:* Tergites dark, lateral margin of I with a band of white scales, II–VI with large laterobasal white spots, III–VI with narrow mediobasal bands. Sternites with basal white bands. *Terminalia:* Basistyle heavily scaled (omitted from figure), with a prominent apical setose lobe and a setose basal lobe. Dististyle stongly forked and bearing a number of hairs and bristles. Ninth sternite very large.

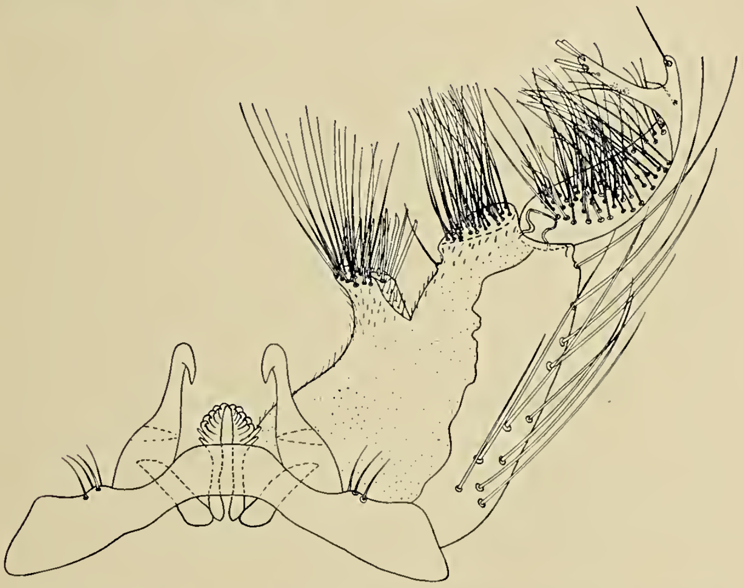

FIG. 14. *A.* (*Stegomyia*) *mediopunctatus* var. *perplexus.* Male terminalia (Palawan).

Female. Wing length about 2.8 mm. Similar to male except as follows: Palpus approximately one fourth to one fifth as long as the proboscis, apex broadly white. Tarsal claws equal, unidentate on fore and midlegs, simple on hind legs.

LARVA: *Head:* Antenna smooth, tapering slightly from base to apex; antennal hair single, small, spine-like, inserted medially or beyond the middle. Mouth brushes with comb-like tips. Hair 4 with 5–8 branches; 5 single; 6 with 2; 7 with 2; 8 single; 9 with 1–3; 12 with 2–4; 13 with 1–2; 14 single; 15 with 2–4; 17, 18, and 20 with 2. Mentum with 10–12 lateral teeth. *Thorax:* Prothoracic hair 1 with 2–3 branches; 2 single; 3 double. Mesothoracic hair 9 single, long, stout, frayed; 10 and 12 single, as long as 9 but more slender and smooth; 11 single, small; a sharp spine on the tubercle that is about one half as long as 11. Metathoracic hair group similar to above except that 12 is much

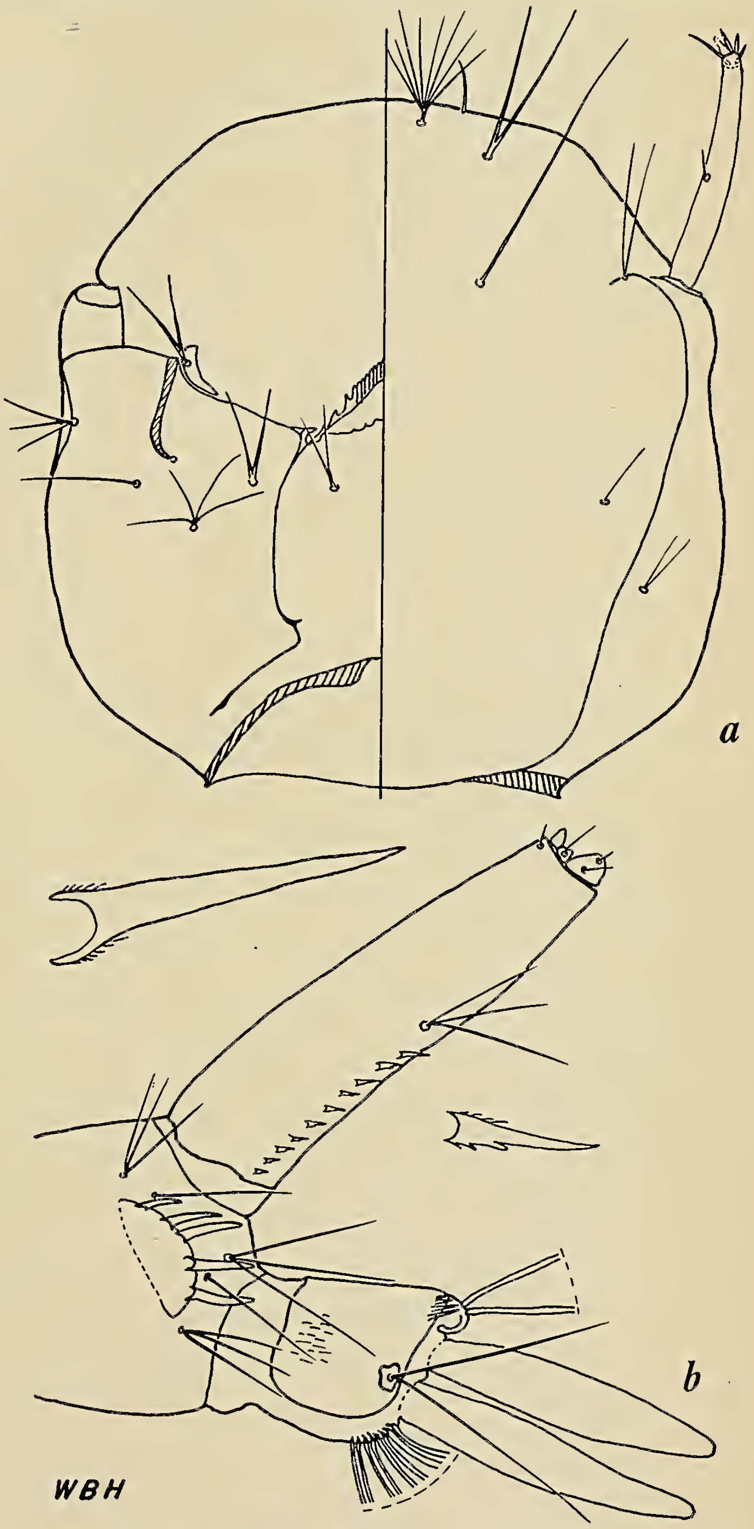

FIG. 15. *A.* (*Stegomyia*) *mediopunctatus* var. *perplexus.* Larva (Palawan). *a*, Head; *b*, terminal segments.

reduced. *Abdomen:* Stellate hairs present. Dorsolateral hairs on I and II double. Lateral hair on I single; on II–VI double, occasionally with 1 or 3 branches. Pentad hair 1 with 2–3 branches; 2 and 4 single; 3 with 3–4; 5 with 2–4. Comb with a row of 4–7 strong teeth on a sclerotized plate, teeth finely fringed at base. Siphon smooth, without acus, index 2.2–3.2; 5–15 pecten teeth in a straight or irregular row, each with 1 or 2 denticles and a fine fringe ventrally, sometimes also finely fringed dorsobasally; siphon hair tuft triple, length less than width of siphon (the siphon shown in Fig. 15 is abnormally narrow). Anal plate incomplete, with a small patch of spines laterally on the posterior dorsal margin, *lh* double, arising from a membranous area in plate; *isc* and *osc* single; ventral brush with 8 single stout hairs borne on a barred area, barred area may be weakly connected laterally. Anal gills rather narrow, bluntly rounded at tip, subequal, 1.5–1.8 times longer than anal plate.

BIONOMICS: Only three collections of this species were made, two adult and one larval. The adults were captured in open woods (one female was taken attempting to bite humans) and the larvae were collected from bamboos.

DISTRIBUTION: *Specimens examined.* R.K.L. Palawan: 5 males, 12 females, 4 sets assoc. skins, 10 larvae, Irahuan River (Johnson, Laffoon); 2 males, 7 females, Bacungan (Laffoon); 1 female, Puerto Princesa (Johnson, Laffoon).

Previously not reported from other than the type series.

DISCUSSION: The identification of the Palawan specimens was confirmed by direct comparison with the types.

According to Barraud (1934: 231), the type form, var. *submediopunctatus* Barraud, and var. *sureilensis* Barraud all differ from *perplexus* in having the fifth hind tarsal segment all dark (occasionally some pale scaling at the base only, however).

The varietal status assigned this mosquito by Barraud (1934: 231) is utilized here because of the lack of information sufficient to establish it either as a subspecies or as a full species.

Aedes (Stegomyia) albolineatus (Theobald)

Fig. 16

1904. *Scutomyia albolineatus* Theobald, Entomologist 37: 77 (female). Type locality: Malaya. Ampang jungle, nr. Kuala Lumpur (Leicester). Type: Female (holotype) in B.M.†

Barraud, 1934: 243 (adult, larva). Knight and Rozeboom, 1946: 84 (adult, pupa, larva, systematics).

DISTRIBUTION: *Specimens examined.* U.S. N.M. and R.K.L. Luzon: Olongapo, Lubid Pt., Grande Island, and Zig Zag Pass, all in Subic Bay area, Zambales Prov. Samar: Osmena; Shohoton Springs, Basey River. Balabac: Cape Melville. Mindanao: San Ramon, City of Zamboanga Prov.; Mercedes, Zamboanga Prov., Zamboanga, City of Zamboanga Prov. A.N.S.P. Leyte: Tacloban; Dagami; Burugwan River; Diit River, Tacloban (Roberts). B.M. Basilan (McGregor). C.A.S. Mindoro: San Jose (Ross).

Outside the Philippines, this species is

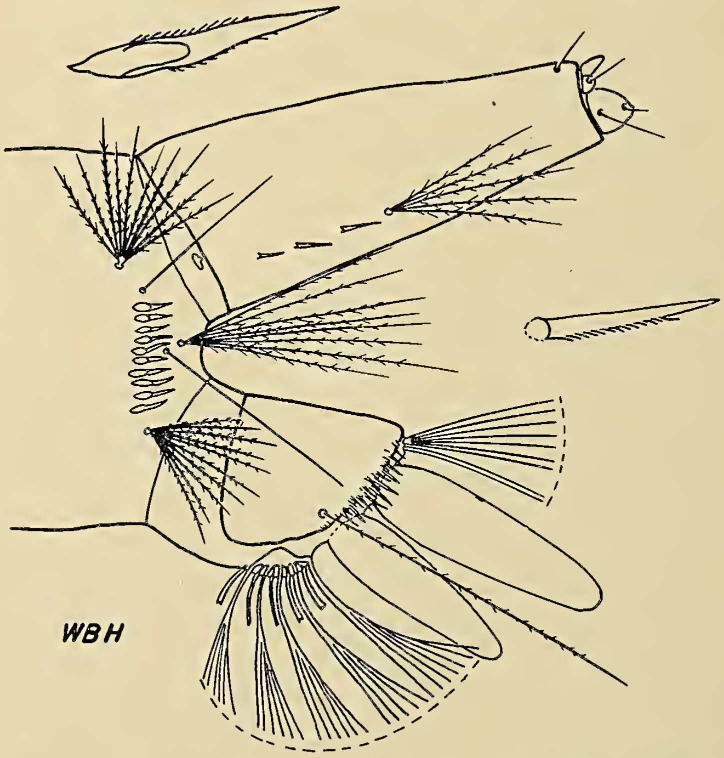

FIG. 16. *A.* (*Stegomyia*) *albolineatus.* Larval terminal segments (Luzon).

known from the Solomon Islands, New Guinea, Admiralty Islands, Borneo, Sangir Islands, Ceram, Saparoea, Krakatoa Group, Sumatra, Riouw, Venaten Island, Java, Celebes, Boeton, Kabaena, Soemba, Indo-China, Malaya, and Assam.

DISCUSSION: The type female was found to differ slightly from the Philippine material in having the subapical black area of the hind femur extended completely across the anterior surface, and in having all of the hind tarsal bands incomplete mesally.

Aedes (Stegomyia) boharti Knight and Rozeboom

Fig. 17

1932. *Aedes* (*Stegomyia*) *albolineatus* (Theobald). Bonne-Wepster and Brug, Geneesk. Tijdschr. v. Nederland. Indië 72: 60. Fig. 14, male terminalia. Also, in part, male description.

1946. *Aedes* (*Stegomyia*) *boharti* Knight and Rozeboom, Biol. Soc. Wash., Proc. 59: 90 (males, females, pupae, larvae). Type locality: Philippines. Osmena, Samar (McMillan and MacMillan). Type: Male (holotype) in U.S.N.M.† With assoc. larval and pupal skins. Terminalia separated.

DISTRIBUTION: *Specimens examined.* U.S. N.M. and R.K.L. Luzon: Olongapo, Lubid Pt., Grande Island, and Zig Zag Pass, all in Subic Bay area, Zambales Prov. Leyte: Balinsasayao; Mt. Lobi, Dagami. Samar: Osmena. Palawan: Irahuan River; Bacungan. Culion: Pilapil. Balabac: Cape Melville. Mindanao: San Ramon, City of Zamboanga Prov.; Zamboanga, City of Zamboanga Prov.; Mercedes, Zamboanga Prov. A.N.S.P. Leyte: Lagolago, Baybay; Tacloban; Dagami (Roberts). U.S. N.M. Mindanao: Janga, Tugbok, City of Davao Prov. (Enke, Hoogstraal); Calinan, Davao Prov. (Enke, Hoogstraal); Beto, Dansalan, Dansalan City Prov. (Enke, Gutierrez, Corcega); nr. Lanao–Cotabato boundary along Parang–Malabang hwy. (Enke, Hoogstraal); Madaum, Davao Prov. (Werner); Parang (Paullus).

Outside the Philippines known only from an unnamed locality in the Netherlands East Indies (Bonne-Wepster and Brug, 1932: 60, as *albolineatus*, in part).

DISCUSSION: This species is very similar to *albolineatus*, some larval specimens being indistinguishable from that species. The adults may be distinguished by the presence of broad white scales ventrally on *ppn* of *boharti*. All of the *ppn* scaling is dark in *albolineatus*.

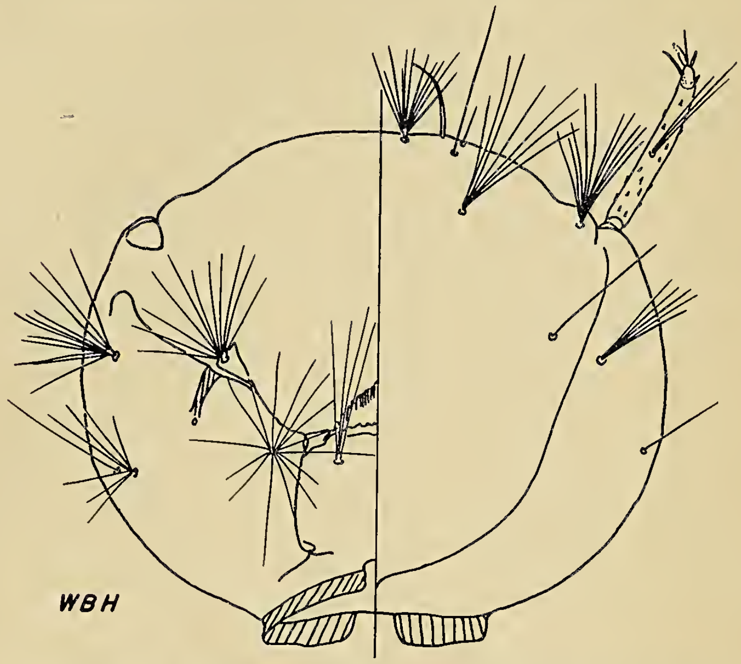

FIG. 17. *A.* (*Stegomyia*) *boharti*. Larval head (Mindanao).

Aedes (Stegomyia) sp. near **boharti**

In the U.S.N.M. there is a female specimen (P1157–2) with associated larval skin, reared from a rot hole at Madaum, Davao Prov., Mindanao (Werner, 16–X–46), that resembles *boharti* except for all three scutellar lobes being covered with broad black scales. The larva is Type D, *boharti*. Entered in the U.S. N.M. collection as *Stegomyia* sp. 44.

Aedes (Stegomyia) arboricolus Knight and Rozeboom

Fig. 18

1946. *Aedes* (*Stegomyia*) *arboricolus* Knight and Rozeboom, Biol. Soc. Wash., Proc. 59: 90 (males, females, pupae, larvae). Type locality: Philippines. Shohoton Springs, inland on Basey River, Samar (Knight). Type: Male (holotype) in U.S.N.M.†

With assoc. larval and pupal skins. Terminalia separated.

DISTRIBUTION: *Specimens examined.* Type series. Samar: Shohoton Springs, inland on Basey River.

Unknown outside the Philippines.

DISCUSSION: In the type description of this species it was stated that *arboricolus* was distinguishable from the type description of *pseudalbolineatus* Brug only on the basis of the markings of the third hind tarsal segment of the female. Since that time the senior author has had the opportunity of examining the type male and the allotype female of *pseudalbolineatus* in the British Museum. They were found to differ further from *arboricolus* in possessing an area of broad white scales on the lateral margin of the scutum just before the level of the wing base. The hind tarsi of the type male had the basal marking on I–II occupying about one fifth of the segment, and on III between one fifth and one fourth of the segment; in the female the basal marking on I occupies one fifth of the segment, on II one fourth, on III about seven eighths, one pale lateral scale on IV; none of the tarsal bands is complete medially. The scaling of the scutellum, *apn*, and *ppn* was largely similar to that of *arboricolus*. No differences in male terminalia were noted.

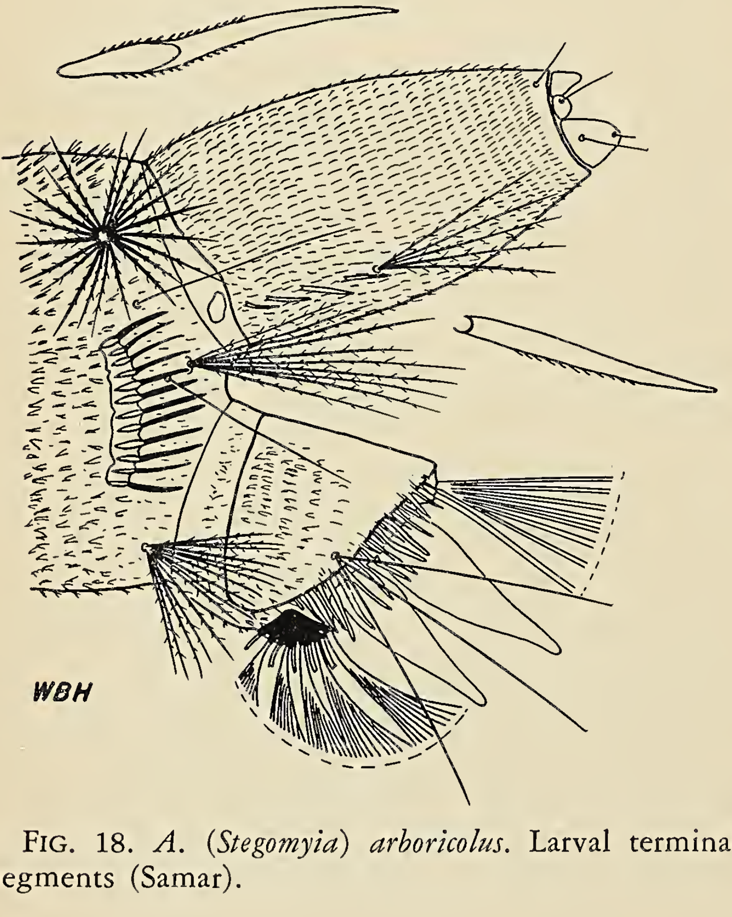

FIG. 18. *A.* (*Stegomyia*) *arboricolus.* Larval terminal segments (Samar).

This species is closely similar to *laffooni* in the adult stage, differing most noticeably from it in the absence of broad white scales on the lateral margin of the scutum.

Aedes (Stegomyia) bambusicolus Knight and Rozeboom

Fig. 19

1946. *Aedes* (*Stegomyia*) *bambusicolus* Knight and Rozeboom, Biol. Soc. Wash., Proc. 59: 94 (males). Type locality: Philippines. Pilapil, Culion Island (Johnson and Laffoon). Type: Male (holotype) in U.S. N.M.† Terminalia separated.

Ross, 1950: 79 (male, female, pupa, larva, biology).

DISTRIBUTION: *Specimens examined.* U.S. N.M. Mindoro: 1 male, 1 female, 1 set assoc. skins, 2 larvae, Labangan River, nr. San Jose (Ross).

Unknown outside the Philippines.

DISCUSSION: The adult of this species may be distinguished from the other members of the *albolineatus* group by the combination of having all three scutellar lobes largely white-scaled and the median scutal stripe extending posteriorly to the scutum.

Aedes (Stegomyia) laffooni Knight and Rozeboom

1946. *Aedes* (*Stegomyia*) *laffooni* Knight and Rozeboom, Biol. Soc. Wash., Proc. 59: 94 (male, females). Type locality: Philippines. San Ramon, Mindanao (Laffoon). Type: Male (holotype) in U.S.N.M.† Terminalia separated.

LARVA: Several larval skins have become available since the publication of the type description of this species. The larva is apparently indistinguishable from *albolineatus* Type B larva, except that all ventral brush elements are borne on the barred area.

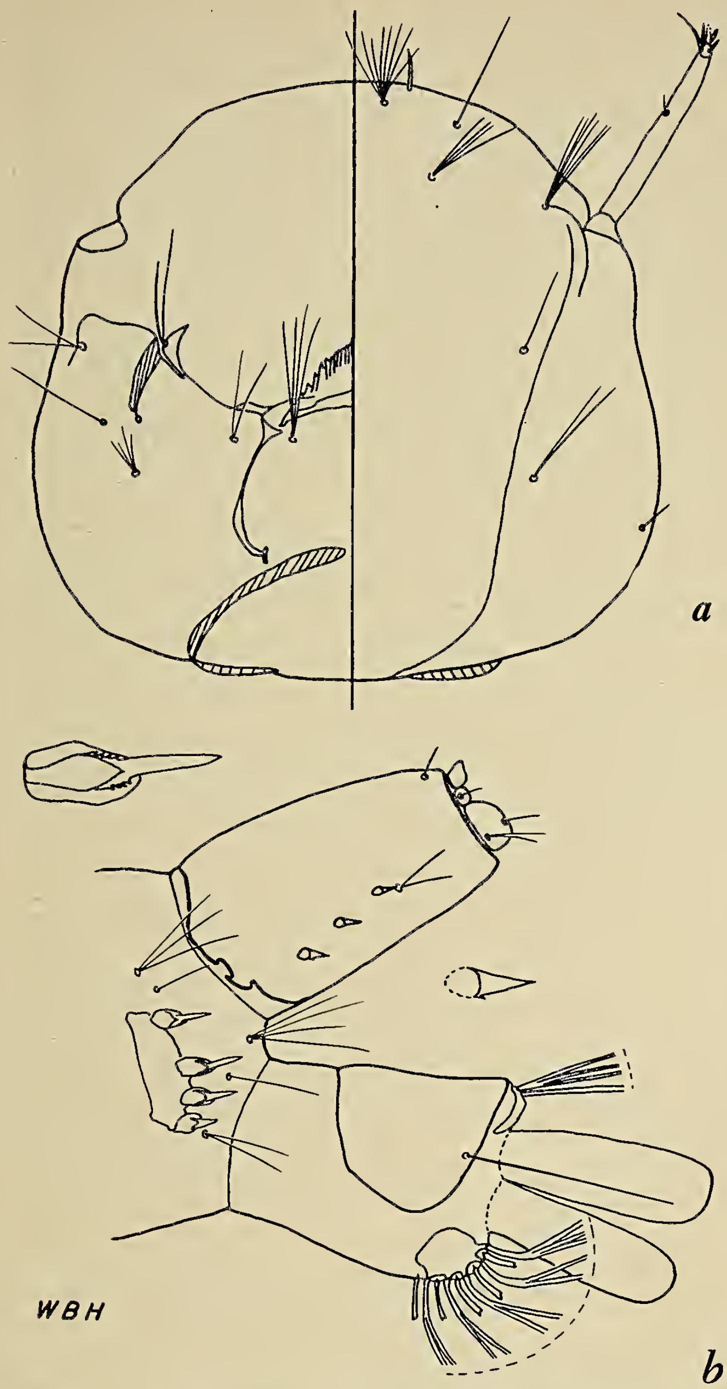

FIG. 19. *A.* (*Stegomyia*) *bambusicolus.* Larva (Mindoro). *a*, Head; *b*, terminal segments.

DISTRIBUTION: *Specimens examined.* U.S. N.M. Mindanao: San Ramon, Zamboanga Prov.; Maasin Village, City of Zamboanga Prov.; 2 sets assoc. skins, Sitio Taglawig, Tagum, Davao Prov. (Hoogstraal); 1 set assoc. skins, Lanao, nr. Lanao–Cotabato boundary along Parang–Malabang hwy. (Enke, Hoogstraal); 1 set assoc. skins, Matanao, Santa Cruz, Davao Prov. (Enke, Corcega).

Unknown outside the Philippines.

DISCUSSION: An examination of the type male and allotype female of *pseudalbolineatus* Brug in the British Museum showed it to be very similar to *laffooni.* The only differences of any importance at all were in the markings of the hind tarsi of the female. In *pseudalbolineatus* female, the basal band on hind tarsal III occupies seven eighths of the segment, and only one pale basal scale occurred on IV. It seems extremely likely that when more material is available from the Netherlands East Indies, from the Philippines, and from the intervening regions, these two will be found to be either synonyms or at the most only subspecies. As pointed out previously, this species is closely similar to *arboricolus.*

Aedes (Stegomyia) hoogstraali Knight and Rozeboom

Fig. 20

1946. *Aedes* (*Stegomyia*) *hoogstraali* Knight and Rozeboom, Biol. Soc. Wash., Proc. 59: 92 (males, females, pupae, larvae). Type locality: Philippines. Subic Bay, Zambales Province, Luzon (Zolick and Zedeck). Type: Male (holotype) in U.S.N.M.† With assoc. larval and pupal skins. Terminalia separated.

DISTRIBUTION: *Specimens examined.* U.S. N.M. Luzon: Subic Bay, Zambales Prov. Balabac: Cape Melville (Laffoon). Culion: 1 larva, Pilapil (Johnson, Laffoon). C.A.S. Mindoro: San Jose (Ross).

Unknown outside the Philippines.

DISCUSSION: While examining types in the British Museum, the senior author discovered that the female type specimen of *Culex impatibilis* Walker, which Edwards (1932: 162) had made a synonym of *aegypti*, is in actuality a member of the *albolineatus* complex. This specimen was identified as the type by E. A. Waterhouse and since Walker's description mentions only the male, there is some question as to the validity of this type specimen. This specimen, which is from Makassar, Celebes (Wallace), has the scutum badly rubbed, the legs entirely missing except the femur, tibia, and first tarsal segment of one hind leg, and all but the first two segments of the abdomen missing. However, sufficient scaling remains to key the specimen to *hoog-*

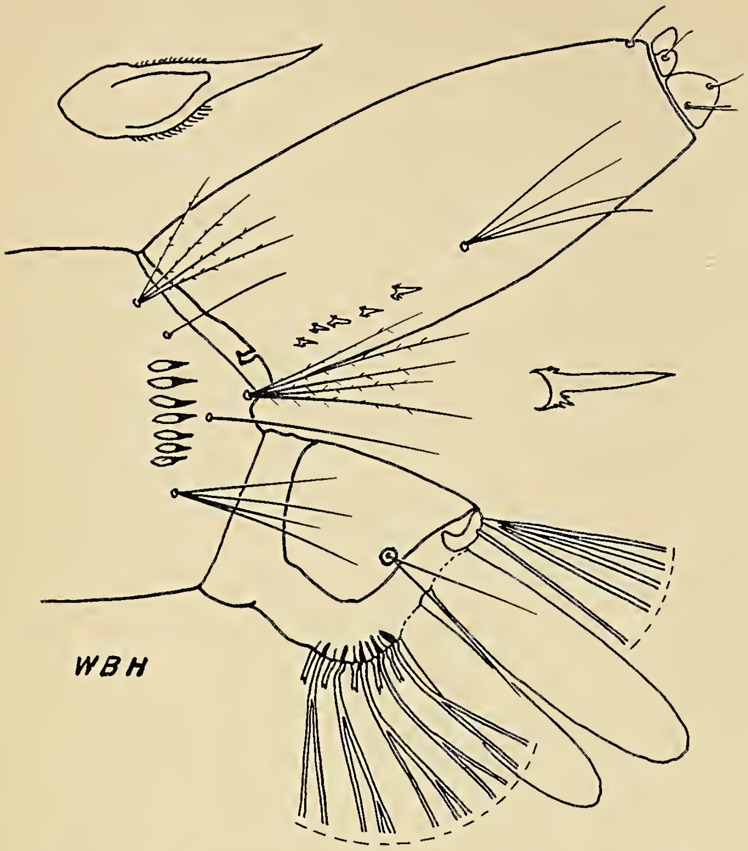

FIG. 20. *A.* (*Stegomyia*) *hoogstraali.* Larval terminal segments (Culion).

straali in the key given by Knight and Rozeboom (1946: 83) but not enough to differentiate the two. Until more material of this species is available from the Celebes, it will not be possible definitely to determine the status of *hoogstraali.* However, pending such an event the name *hoogstraali* is maintained for the Philippine material.

This species may be distinguished easily from all the other members of the *albolineatus* group by the narrow-curved creamy-white scales on *apn* and *ppn.*

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News Notes

The following publication of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, Tokyo, Japan, has been received. Each report includes a list of all of the reports previously published, their distribution, and rules for obtaining them.

River Control and Utilization in Japan, by Robert Y. Grant. Report No. 149. 161 pp., 57 figs., 80 tables, 2 maps.

Heads of government scientific research organizations in British Commonwealth countries conferred in Australia early in 1952. This British Commonwealth Scientific Official Conference was the first to be held outside the United Kingdom. The last Conference met in London in 1946.

The 1946 Conference reviewed administrative aspects of scientific research within the British Commonwealth and made recommendations to achieve closer collaboration. As a result, British Commonwealth Scientific Offices have been established in London and Washington, and the exchange of scientific information between different parts of the British Commonwealth has been greatly facilitated.

"Specialist conferences," arising out of this Conference have been held on such subjects as geology and mineral resources, type cultures of bacteria and fungi, radio research, fuel research, and animal and plant nutrition.

Representatives in the fields of scientific, industrial, agricultural, and medical research attended the Conference in Australia. Problems discussed were of an administrative rather than a technical character, and further collaboration in scientific work was planned.

Delegates from the United Kingdom (including the Colonies), Canada, South Africa, New Zealand, Southern Rhodesia, Pakistan, and Ceylon, as well as a number of Australian delegates, attended. An observer from the United States was also present.

The Conference opened in Canberra on February 18 and closed in Melbourne on March 7, 1952. The formal session was broken by visits to enable delegates to study Australian developmental problems.—N.S.N.

Information has been received from the Pacific Science Council Secretariat that the date for the Eighth Pacific Science Congress has been set for November 16 to 28, 1953. The Congress will be held in the University of the Philippines buildings at Quezon City. Correspondence on all matters concerning the Eighth Congress is to be addressed to the Secretary-General, Dr. Patrocinio Valenzuela, National Research Council of the Philippines, University of the Philippines, Quezon City.

The Pacific Science Council vacancy created by the death of Sir Peter Buck, December 1, 1951, has been filled by Bernice P. Bishop Museum, Representative Institution for Hawaii, with the appointment of Dr. Cyril E. Pemberton, entomologist with the Experiment Station of the Hawaiian Sugar Planters' Association, Honolulu. Dr. Pemberton has been closely associated with the Pacific Science Association, having been chairman of the Standing Committee on Economic Entomology between the Sixth and Seventh Pacific Science Congresses. He is presently a member of the Standing Committee on Crop Improvement in the Pacific Area.

pasted on proper page, and point of insertion should be clearly indicated.

Original copy and one carbon copy of manuscript should be submitted. The author should retain a carbon copy. Although due care will be taken, the editors cannot be responsible for loss of manuscripts.

Introduction and summary. It is desirable to state the purpose and scope of the paper in an introductory paragraph and to give a summary of results at the end of the paper.

Dictionary style. It is recommended that authors follow capitalization, spelling, compounding, abbreviations, etc., given in *Webster's New International Dictionary* (unabridged), second edition; or, if desired, the *Oxford Dictionary.* Abbreviations of titles of publications should, if possible, follow those given in U. S. Department of Agriculture *Miscellaneous Publication 337.*

Footnotes. Footnotes should be used sparingly and never for citing references (see later). When used, footnotes should be consecutively numbered by superior figures throughout the body of the paper. Footnotes should be typed in the body of the manuscript on a line immediately below the citation, and separated from the text by lines running across the page.

Citations of printed sources. All references cited should be listed alphabetically by author at the end of the paper, typed double-spaced. References to books and to papers in periodicals should conform to the following models:

BATZO, RODERICK L., and J. K. RIPKIN. 1849. *A treatise on Pacific gastropods.* vii + 326 pp., 8 figs., 1 map. Rice and Shipley, Boston.

CRAWFORD, DAVID L. 1920*a*. New or interesting Psyllidae of the Pacific Coast (Homop.). *Ent. News* 31 (1): 12–14.

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In the text, sources should be referred to by author, date, and page, as follows: "It was noted (Rock, 1916: 18) that . . ." or "Rock (1916: 21–24) says . . ."

Quotations. Quoted matter of fewer than five printed lines (about 200 characters) should be given in the text in the usual form, using double quote marks. Longer quotations should be set flush with left margin. The author is responsible for the accuracy of quoted material.

Numbers. Decimals, measurements, money, percentages, time; enumerations in which any figure is 10 or over; and isolated enumerations of 10 and over should be given in Arabic figures, rather than spelled out, except when the number begins a sentence.

ILLUSTRATIVE MATTER

Illustrations should accompany manuscript, on separate sheets. Often more valuable than a photograph is a good line drawing, which may be reproduced by the zinc etching process.

Figures and graphs. Copy for figures and graphs should always be drawn large enough to allow for at least one-third reduction by the engraver. Copy should consist of carefully prepared line drawings in one color only, drawn in India ink on plain white drawing paper or tracing cloth. Co-ordinate paper with lines in light blue (a color which will not show in a photograph) may be used; but co-ordinates which should appear in the finished graph must be drawn in India ink. If original figures may not be conveniently submitted with manuscript, duplicate rough sketches or photographic prints may be furnished to aid the editors in their decisions.

It is strongly urged that an indication of scale be incorporated as a part of all drawings in which magnification and size are critical considerations.

Photographs. Photographs should be chosen for clarity in portraying essential information. They should be printed for contrast, on glossy paper, and should be sent unmounted. They should be identified with serial number written in soft pencil on the back to correspond with list of captions.

Tables. Tabular matter should be kept to a minimum. Each table should be typed on a separate page, and its position indicated on the manuscript.

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VOL. VI JULY, 1952 NO. 3

PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

IN THIS ISSUE: Matsubara and Iwai—*Studies on Japanese Gempylid Fish* ● St. John — *Monograph of the Genus* Isodendrion ● Morris — *Spawning Behavior of a Cottid Fish* ● Leopold — *Dew as a Source of Plant Moisture* ● Levi-Castillo — Aedes camposanus *as a Valid Species* ● NEWS NOTES

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Studies on Some Japanese Fishes of the Family Gempylidae

KIYOMATSU MATSUBARA and TAMOTSU IWAI[1]

THOUGH THE FISHES of the family Gempylidae have long been of interest to ichthyologists and though considerable literature concerning this family has accumulated, the group still is far from being satisfactorily understood.

Since the publication of "Gempylidae of Japan" by Dr. Toshiji Kamohara in 1938, some additional facts have come to light, and several discrepancies have been found to exist between his descriptions and our specimens. The present paper, supplementing Kamohara's, treats seven species of the family, referred to the genera *Neoepinnula*, *Epinnula*, *Mimasea*, *Gempylus*, *Rexea*, *Nealotus*, and *Promethichthys*. The specimens thus far examined were all taken by deep-sea trawlers off the Pacific coast of Japan at a depth of about 100 fathoms, and all are deposited in the Department of Fisheries, Faculty of Agriculture, Kyoto University. *Neoepinnula*, described as a new genus, is based on *Epinnula orientalis* Gilchrist and von Bonde.

The family Gempylidae is closely related to the Scombridae and is apparently an offshoot from that family, divergent in the direction of the Lepidopidae and Trichiuridae. This family is distinguished, from the Scombridae at least, by having the dentition strong, the body usually elongated, and the ventral fin small, often reduced to a single spine, or even absent in adults.

The few species comprising this family live in the high seas and are widely distributed in warm regions throughout the world.

The measurements of various parts of the body were made in the same way as those made by the senior author in his study on the scorpaenoid fishes of Japan (Matsubara, 1943: 6–7). We have carefully observed the gill rakers stained by alizarin red and cleared by potassium hydroxide.

Acknowledgments: We wish to express our sincere gratitude to Mr. Vernon E. Brock, Dr. Carl L. Hubbs, Mr. T. Abe, Dr. T. Kamohara, and Mr. M. Nakamura, all of whom helped us in various ways. We are also greatly indebted to Messrs. G. Abe and S. Noda for assistance in obtaining material. Expenses for investigations of deep-sea fishes were defrayed from 1943 to 1945 by a research fund from Viscount Keizo Shibuzawa and since 1948 by a grant from the Japanese Ministry of Education.

NEOEPINNULA new genus

The genus *Epinnula* was established by Poey (1854: 369) for the accommodation of his new species *E. magistralis*, which he obtained at Havana, Cuba. In 1924 another new species, *E. orientalis*, was added to this genus by Gilchrist and von Bonde (1924: 15, pl. 4, fig. 1) on the basis of a specimen taken from Natal, South Africa. On careful examination of specimens of these two species, we found some remarkable differences, on the basis of which we erect a new genus *Neoepinnula*, with *N. orientalis* (Gilchrist and von Bonde) as genotype.

---

[1] Department of Fisheries, Faculty of Agriculture, Kyoto University, Nagahama, Maizuru, Japan. Manuscript received in two parts, on May 2 and November 9, 1950. These parts have been amalgamated and edited by Dr. Carl L. Hubbs of the Editorial Board of *Pacific Science*.

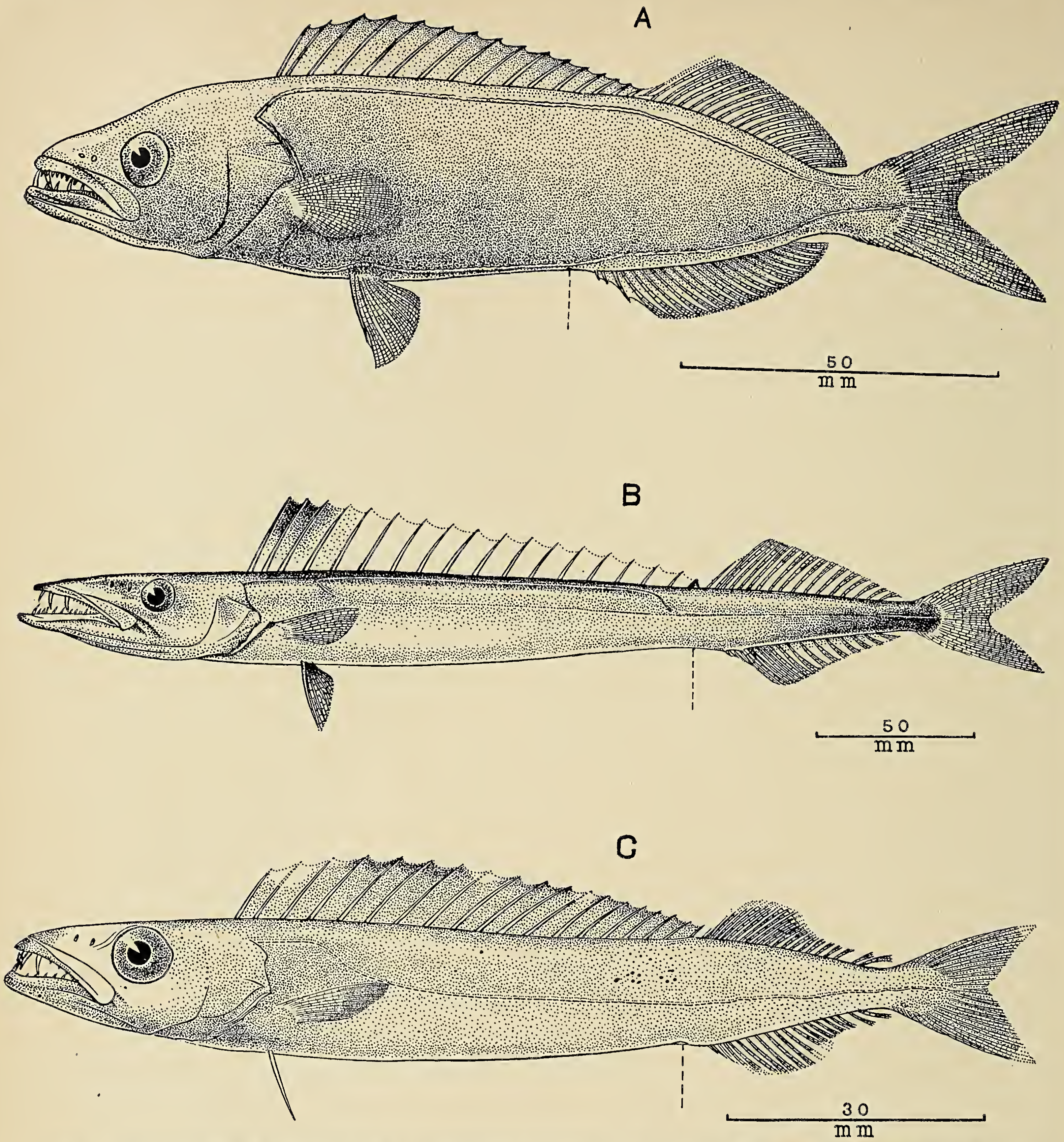


FIG. 1. Three species of Gempylidae. A, *Neoepinnula orientalis* (No. 4258); B, *Mimasea taeniosoma* (No. 4114); C, *Promethichthys prometheus* (No. 4101). Drawn by Ryokai Ito.

Body rather stout, fusiform, and compressed, covered with minute imbricated scales. Several fangs, some depressible, on upper jaw near tip of snout. Vomer and palatines toothed. Two lateral lines, originating together above upper angle of gill opening. Dorsal fin inserted behind upper angle of gill opening; dorsals barely connected; spines rather feeble and flexible. Ventrals I, 5. No finlets. Tail not keeled. Gill raker at angle of first arch (Fig. $2A_3$) T-shaped; its inner surface armed with minute spines. Lining of buccal and branchial cavities and peritoneum black.

This genus differs from *Epinnula* as indicated in the key.

KEY TO THE GENERA OF JAPANESE GEMPYLIDAE

1a. Caudal peduncle with a keel on each side; scales of body unique, each large scale being surrounded by a network of small pored tubular scales; lateral line greatly undulated, reaching nearly to both back and belly. . . . . *Lepidocybium* (= *Xenogramma; Lepidosarda*)

1b. Caudal peduncle without lateral keel; scales not surrounded by a network of small-pored tubular scales; lateral line not greatly undulated.

  2a. Abdomen keeled; skin spinigerous; lateral line obscure. Ventrals I, 5. . . . . . . *Ruvettus*

  2b. Abdomen not keeled; skin smooth; lateral line well-developed.

    3a. Ventrals well-developed, their rays I, 5; no detached finlets.

      4a. Body fusiform (depth about one fourth standard length); palatines toothed; lower lateral line running near lower contour of body; snout (Fig. 5C) not projecting beyond anterior extremities of premaxillaries.

        5a. Vomer with 1 to 3 teeth on each side; the 2 lateral lines originating together at upper angle of gill opening; dorsal fin inserted behind upper end of gill opening; dorsal spines feeble and flexible; inner surface of gill raker at angle of first arch (Fig. $2A_3$) armed with 2 rows of minute spines; lining of buccal and branchial cavities black . . . . *Neoepinnula*

        5b. Vomer edentulous; the 2 lateral lines bifurcating below membrane between fifth and sixth dorsal spines; dorsal fin inserted above posterior margin of preopercle; dorsal spines rather strong and pungent; inner surface of gill raker at angle of first arch not armed with spines; lining of buccal and branchial cavities pale . . . . *Epinnula*

      4b. Body elongate (depth about one tenth standard length); palatines edentulous; lower lateral line running along middle of body; snout (Fig. 5A) projecting far beyond anterior extremities of premaxillaries . . . . *Mimasea*

    3b. Ventrals greatly reduced or absent; detached finlets always present.

      6a. Body greatly elongate (depth contained more than 12 times in standard length); detached finlets 5 to 7; ventrals minute, their rays I, 4 to I, 5, the soft rays hardly visible without aid of a lens; maxillary largely hidden under infraorbital membrane; gill raker at angle small, triangular; snout (Fig. 5B) projecting far beyond tips of premaxillaries. Two lateral lines, both originating above angle of gill opening . . . . *Gempylus*

      6b. Body moderately elongate (depth contained less than 9 times in standard length); detached finlets usually 2; ventrals absent or each represented by a single spine; maxillary wholly exposed; gill raker at angle T-shaped; snout (Figs. 5 D–E) projecting little or not at all beyond tips of premaxillaries.

        7a. Two lateral lines; ventral fins absent in adult . . . . *Rexea*

        7b. One lateral line; ventral fins usually present.

          8a. A dagger-shaped spine followed by a minute free spine behind vent; lateral line straight; each pore in lateral line with short upper oblique branch only; scales nonimbricate . . . . *Nealotus*

          8b. No free spines behind vent; lateral line abruptly curved downward anteriorily; each pore in lateral line behind the anterior curved part bearing short upper and lower oblique branches; scales imbricate . . . . *Promethichthys*

Neoepinnula orientalis
(Gilchrist and von Bonde)
Figs. 1A, 2A, 5C

Epinnula orientalis Gilchrist and von Bonde, 1924: 15, pl. 4, fig. 1; Barnard, 1927: 790; Kamohara, 1936*a*: 18; 1938*a*: 48, pl. 3, fig. 4; 1938*b*: 20; 1940: 95, fig. 44; 1942: 108; Smith, 1949: 311, fig. 865.

MATERIAL DESCRIBED: No. 1970 (the numbers refer to Matsubara's Fish Collection, in which each specimen bears a separate number), 143 mm. in standard length (176.5 mm. in total length), off Owase, Kumano-Nada, January 4–9, 1936; Nos. 4258 and 4259, 129 and 179 mm. (159 and 219 mm.), off Owase, Kumano-Nada, January, 1937; No. 4430, 154.5 mm. (185 mm.), off Owase, Kumano-Nada, April, 1937; No. 5490, 122.5 mm. (151 mm.), off Choshi, Chiba Prefecture, November 20–26, 1937; No. 6235, 121.5 mm. (151 mm.), off Heta, Suruga Bay, March 26, 1939.

Since the publication of Gilchrist and von Bonde's description and figure of this rare fish in 1924, there was no record other than from South Africa until 1936, when Kamohara described it from the vicinity of Kochi, Japan. It is apparently known only from these two localities.

D. XVI, I, 19–20; A. III, 19–20; P. 13–14; V. I, 5; Br. 7. Head 3.21 to 3.44 in body length; depth 3.92 to 4.21. Snout 2.64 to 2.92 in head; eye 4.75 to 6.12; interorbital space 3.63 to 4.06; upper jaw 2.01 to 2.26; depth of caudal peduncle 4.00 to 4.75; pectoral 1.87 to 2.53; ventral 2.38 to 3.25; longest (4th) dorsal spine 3.30 to 4.00; longest (3rd) soft dorsal ray 2.74 to 4.22; caudal 1.17 to 1.41.

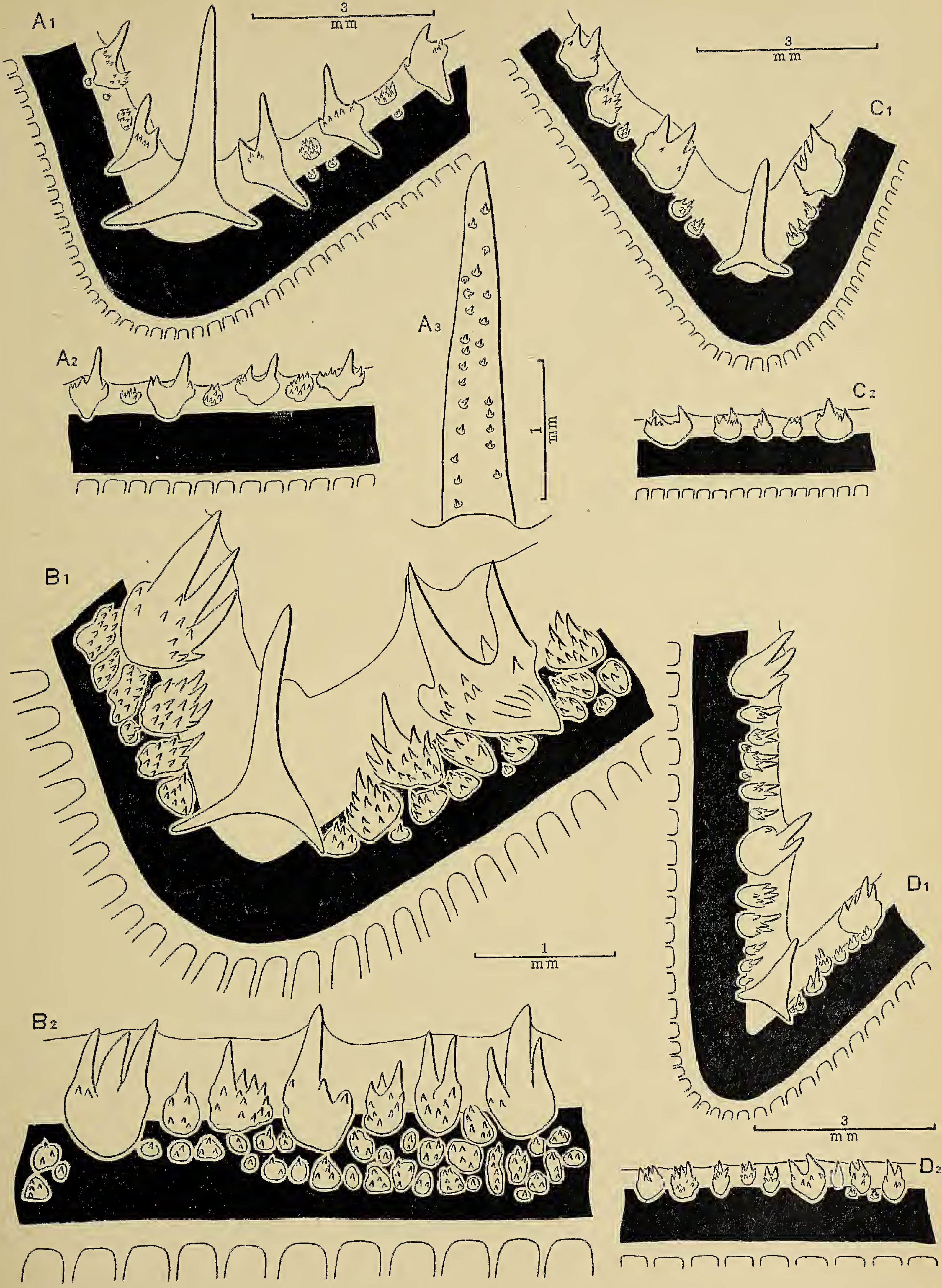
Body fusiform, rather stout and strongly compressed; depth about equal to length of head behind anterior nostril. Jaws rather obtuse, lower projecting beyond upper when mouth is closed. Mouth large, maxillary exposed, about 3 times as broad as least infraorbital width, extending to below anterior edge of pupil or approximately to below middle of eye. Three or 4 fangs on upper jaw near tip of snout, of which 2 or 3 are immovable and the others depressible; lateral teeth on jaws conical and widely spaced, those of lower jaw much larger than those of upper; a pair of canines near the symphysis of lower jaw, exposed outside the closed mouth; 1 to 3 teeth on each posterior extremity of lateral edges of vomer; a single series of small conical teeth on palatines. Interorbital flattish in small specimens, but slightly convex in larger ones, always much wider than eye.

Upper lateral line gently elevated upward and backward to below base of second or third dorsal spine, then passing directly backward near dorsal base and ending below upper anterior end of base of caudal fin; lower one running downward and slightly backward to immediately below lower edge of base of pectoral, then turning downward and slightly forward, and finally extending near lower contour of body to base of middle caudal ray. Head and body, except maxillaries, lower lip, throat, and branchiostegal membrane, wholly covered with small scales.

Base of spinous part of dorsal about twice as long as that of soft part; soft dorsal about as large as anal fin, which is preceded by 3 small spines. Pectoral slightly longer than ventral, extending to below sixth dorsal spine; ventral inserted a little behind middle of pectoral.

Gill rakers distinctive (Fig. 2A): small, mostly hidden under the skin; each usually with a single cusp and a vertically elongated basal plate, and armed with many small spines; gill raker at angle T-shaped with more

FIG. 2. Outer face of first gill arch in four species of Gempylidae. Bony part of gill arch is black. A_1, A_2, and A_3, *Neoepinnula orientalis*, showing, respectively, right side of region of angle, middle part of lower branch, and inner side of a raker at angle (No. 4259); B_1 and B_2, *Promethichthys prometheus*, showing, respectively, right side of region of angle and middle part of lower branch (No. 4101); C_1 and C_2, *Mimasea taeniosoma*, showing, respectively, left side of region of angle and middle part of lower branch (No. 4114); D_1 and D_2, *Gempylus serpens*, showing, respectively, left side of region of angle and middle part of lower branch (No. 57). Drawn by authors.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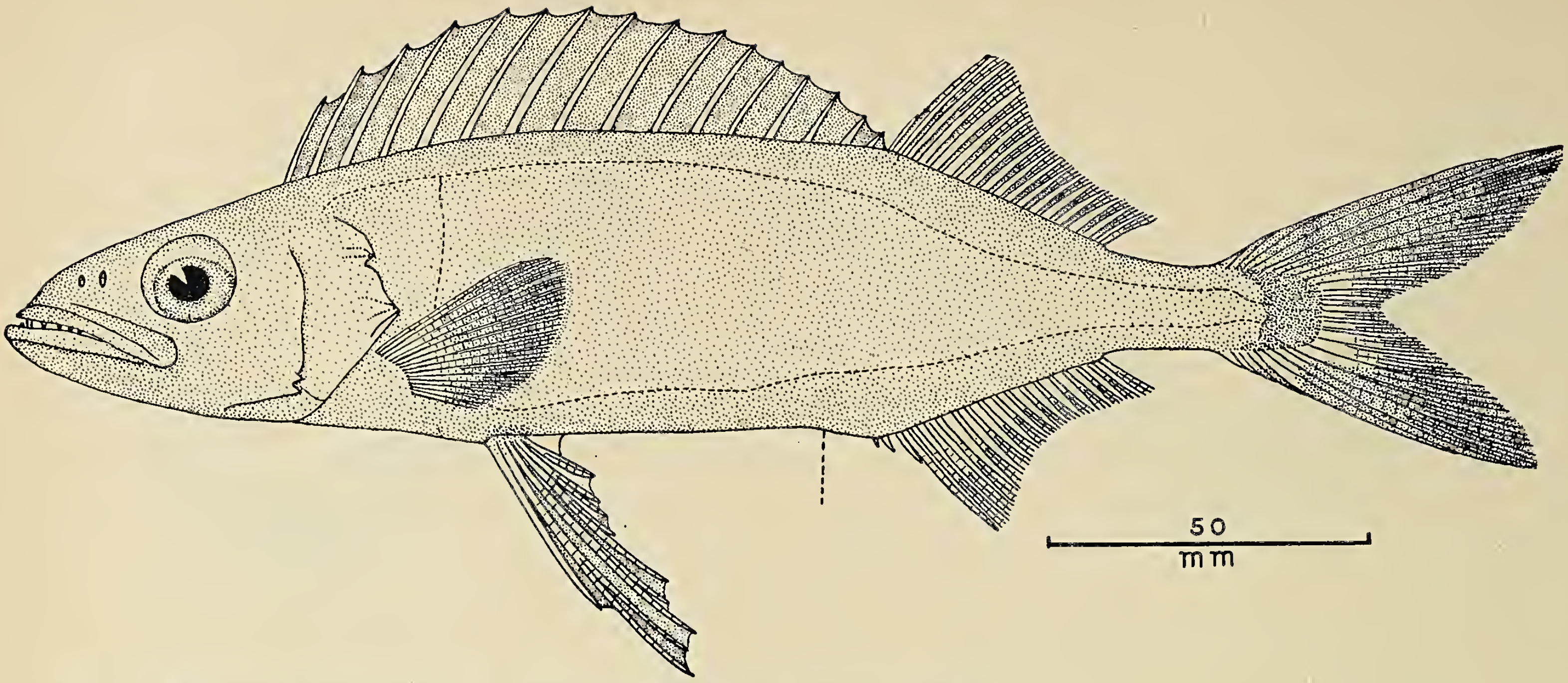

FIG. 3. *Epinnula magistralis* (No. 13961). Drawn by senior author.

than two thirds of length exposed and inner surface armed with 2 longitudinal series of minute spines (Fig. 2A₃).

Color in formalin uniformly bluish brown, not paler below; fins pale except for the blackish spinous dorsal; lining of buccal and branchial cavities black.

REMARKS: Our six specimens agree fairly well with the figure and brief descriptions by Kamohara. In our specimens, however, the ventral origin lies slightly behind the middle of the pectoral, as in those of Kamohara; not behind the tip of the pectoral, as indicated in the original description and figure. We, therefore, identify our fish with some doubt.

EPINNULA Poey

Epinnula Poey (1854: 369—type *E. magistralis* Poey).

Body rather stout, fusiform, and compressed; covered with minute imbricated scales. Several fangs, some depressible, on upper jaw near tip of snout. Vomer edentulous, but palatines with a series of small teeth. Lateral line bifurcating beneath anterior part of spinous dorsal. Dorsal fin inserted before upper angle of gill opening; dorsals barely connected; spines rather stout and inflexible. Ventrals I, 5. No finlets. Tail not keeled. Gill raker at angle of first gill arch T-shaped, with inner surface smooth. Lining of buccal and branchial cavities pale, but peritoneum black.

Epinnula magistralis Poey
Figs. 3–4

Epinnula magistralis Poey, 1854: 369, pl. 32, figs. 3–4; Günther, 1860: 349; Goode and Bean, 1895: 198, pl. 57, fig. 211; Jordan and Evermann, 1896: 880; Kamohara, 1938*a*: 48, pl. 3, fig. 3; 1938*b*: 20; 1940: 93, fig. 43.

MATERIAL DESCRIBED: No. 13961 (Matsubara's Fish Collection), 188 mm. in standard length (242 mm. in total length), off Owase, Kumano-Nada, October 2, 1950.

This species was originally described from a specimen obtained at Havana in September, 1853. There has since been obtained a single specimen from the Caribbean Sea in 1885 (Goode and Bean) and two from Japan (Tosa Bay and Kumano-Nada) in 1938 (Kamohara). Until recently, therefore, this fish has been supposed to be confined to the West Indies. The Japanese specimens, however, differ markedly from the descriptions of Atlantic fish in the length of the ventral fin and in certain numerical characters.

D. XVI, I, 18; A. III, 16; P. 15; V. I, 5; Br. 7. Head 3.13 in body length; depth 3.91; width 9.35; distance from tip of snout to origin of dorsal fin 4.01. Snout 2.88 in head; eye 4.29; fleshy interorbital space 3.65; bony interorbital 4.96; upper jaw 2.35; depth of the caudal peduncle 4.80; pectoral 1.87; ventral 1.25; longest (5th) dorsal spine 2.51; longest (2nd) soft dorsal ray 2.75; longest (1st) anal ray 2.83; caudal 1.06.

Body rather stout, fusiform, and strongly compressed; depth about equal to length of head behind anterior nostril; width about equal to one third the length of head. Upper profile of head slightly elevated before anterior nostril, then nearly straight to insertion of dorsal fin. Snout not projecting beyond premaxillaries. Muzzle bluntly conical; lower jaw projecting beyond tip of snout a distance about one third as long as pupil. Mouth large; maxillary not hidden under infraorbital membrane, extending a little behind anterior border of pupil, the width about twice the least infraorbital width. Two fangs on each side of upper jaw near tip of snout, anterior one of right side depressible, the others immovable; lateral teeth on jaws conical and widely separated; those of lower jaw larger than those of upper; a pair of canine-like teeth near symphysis of lower jaw, exposed outside closed mouth; vomer evidently edentulous; a single longitudinal series of small conical teeth on palatines. Eye round, not entering upper profile of head, about two thirds as long as snout; infraorbital less than half as wide as pupil. Interorbital about 1.2 times as broad as eye; with 4 low longitudinal ridges; space between inner pair of ridges very slightly concave; outer part of outer ridges more or less elevated. Angle of preopercle armed with 2 small but rather pungent spines; opercle strengthened by 2 obscure ridges, not ending in spines.

Lateral line inserted above upper end of gill opening, running backward to point of bifurcation beneath the membrane between fifth and sixth dorsal spines; upper branch running directly backward close to and paralleling dorsal contour of body and ending at base of middle caudal ray; lower branch running directly downward to behind middle part of base of pectoral fin, then passing downward and slightly backward to above origin of ventral, and finally extending along lower contour of body to base of caudal fin. Head and body—except lips, lower jaw, anterior half of maxillary, and branchiostegal membrane—wholly covered with small imbricated scales.

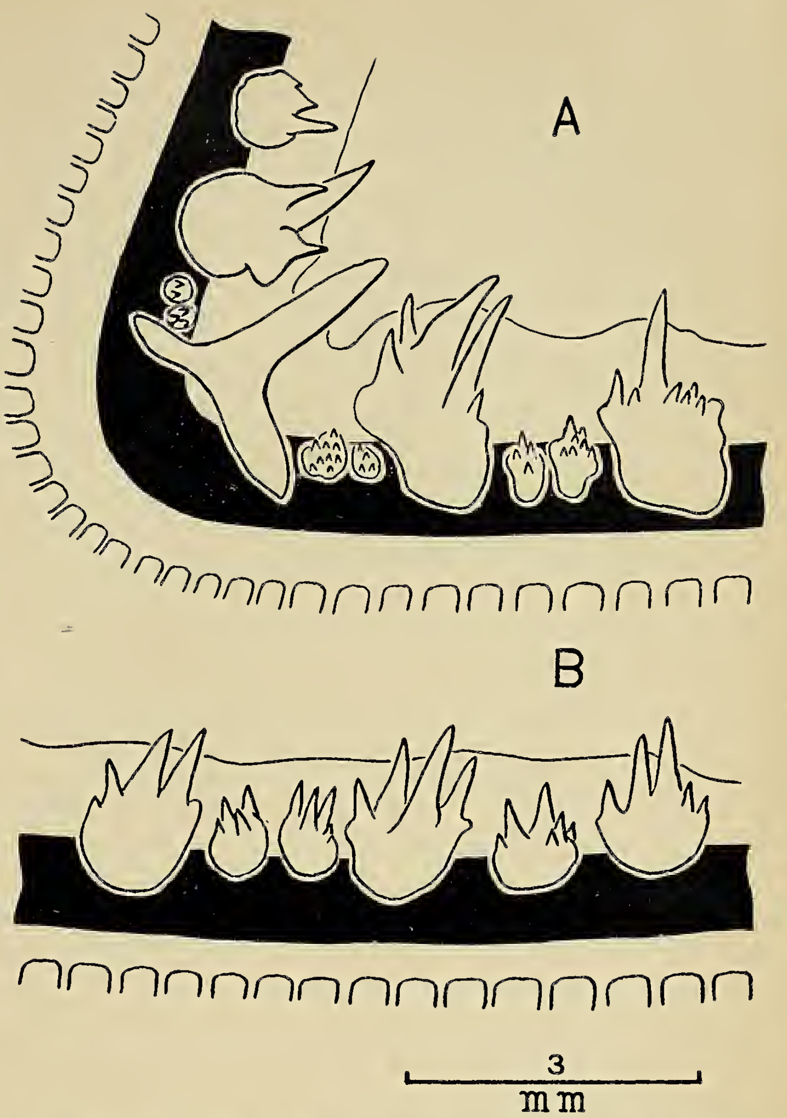

FIG. 4. Outer face of first gill arch in *Epinnula magistralis* Poey. A, region near angle on right side; B, middle part of lower branch on right side. Drawn by authors.

Base of spinous part of dorsal fin about 2.5 times as long as that of soft part; soft dorsal about as long as anal fin and preceded by a weak spine; anal opposite soft dorsal, preceded by 3 spines, the first inserted under base of first soft dorsal ray; margins of soft dorsal and anal shallowly but widely concave. Pectoral rather short, about two thirds as long as ventral, extending to below eighth dorsal spine. Ventral inserted below middle of pectoral, very long, about as long as head behind anterior nostril and extending nearly to vent; ventral spine also very long, about as long as pectoral. Caudal deeply forked.

Gill rakers (Fig. 4) small, mostly hidden under the skin, each usually armed with 3 or 4 sharp cusps and provided with a broad, roundish, never vertically elongated basal plate armed with 1 to 5 small accessory spines; 1 or 2 small accessory rakers, armed with small spines, interpolated between some larger rakers; raker at angle of first gill arch T-shaped, with about one third of its entire length exposed; its inner surface not armed with minute spines.

Color of body when fresh, before preservation, light grayish blue, not paler below; head more or less darker. Interradial membranes of spinous dorsal and those of ventral fin before third soft ray jet-black; basal part of caudal fin dark blue; caudal fin jet-black except for the whitish 8 shorter rays near axis of body; pectoral and rays of soft dorsal spotted with black; anal pale. Buccal and branchial cavities pale, but peritoneum black.

REMARKS: Our single specimen differs from the descriptions of Atlantic specimens in having a larger number of dorsal rays (XVI, I, 18, instead of XV, I, 16), a larger number of anal soft rays (16 instead of 13), and a shorter snout (1.5 times instead of twice the diameter of eye), and in having the longer ventral fin about 1.5 times as long as the pectoral, reaching nearly to the vent rather than being about two thirds as long as the pectoral, and far removed from the vent when the fin is laid back. These discrepancies, however, appear to be attributable largely to the difference in size of the specimens, inasmuch as ours is merely 242 mm. instead of 980 mm. long.

Our specimen agrees well with Kamohara's description (1938*a*: 48, pl. 3, fig. 3) except in having slightly fewer anal soft rays (16 instead of 17) and a somewhat longer ventral fin (the fin 1.25 instead of 1.6 to 1.7 in length of head).

Apart from the generic differences aforementioned, this species may be distinguished from *Neoepinnula orientalis* in having much larger eyes, fewer anal soft rays (16 or 17 instead of 19 or 20), and a longer ventral fin (in our single specimen of this species, 188 mm. in standard length, the ventral measures 1.25 in the head length, whereas in 2 specimens of *N. orientalis*, Nos. 13960 and 4259, 177 and 179 mm. long, this fin measures 3.17 and 3.25, respectively).

E. magistralis appears to be a pelagic species. Its stout body, strong dorsal spines, and colorless buccal and branchial chambers favor this interpretation, which is strongly supported by the fact that it has well-developed ventral fins—at least as indicated by the immature specimen examined by us.

MIMASEA Kamohara

Mimasea Kamohara (1936*b*: 929—type *M. taeniosoma* Kamohara).

This monotypic genus is closely related to *Neoepinnula* and *Epinnula*, with which it agrees in having well-developed ventrals and in lacking detached finlets. It resembles *Gempylus* in form of body and structure of the snout, which is rather sharply pointed, terminates in a large conical cartilaginous process, and projects far beyond the anterior extremities of premaxillaries (Fig. 5A). In other genera of this group the premaxillaries terminate at the anterior extremity of the snout. Thus, the present genus is intermediate between *Neoepinnula* and *Epinnula* on the one hand and *Gempylus* on the other. *Gempylus* is apparently the most specialized of these genera. The species of *Gempylus* have greatly elongated bodies and ventral fins of greatly reduced size, represented by one spine and four or five weak soft rays.

Mimasea taeniosoma Kamohara
Figs. 1B, 2C, 5A

Mimasea taeniosoma Kamohara, 1936*b*: 929, fig. 1; 1938*a*: 47, pl. 3, fig. 3; 1938*b*: 20; 1940: 96, fig. 45.

MATERIAL DESCRIBED: No. 4114, 280 mm. in standard length (322.5 mm. in total length), off Owase, Kumano-Nada, January, 1937.

This rare species, the genotype of *Mimasea*, was based on three specimens taken near Kochi City. Later, two other specimens, since lost, were taken by him at the same locality. Our single specimen differs in some features from Kamohara's rather brief description.

D. XVIII, 16; A. I, 16; P. 13; V. I, 5; Br. 8. Head 3.83 in body length; depth 9.82. Snout 2.09 in head; eye 6.96; interorbital 6.96 (bony width 7.86); upper jaw 2.15; depth of caudal peduncle 8.17; pectoral 2.70; ventral 3.32; longest (2nd) dorsal spine 2.61; longest (3rd) anal ray 3.95; caudal 1.74.

Body greatly elongated and strongly compressed, at its middle about half as wide as deep. Snout (Fig. 5A) rather sharply conical; lower jaw also sharply pointed, projecting beyond tip of snout a distance equal to half diameter of eye. Mouth large; maxillary not hidden under infraorbital membrane, extending to below front edge of eye, the width at the extremity a little greater than the least infraorbital width. Three fangs on each side of upper jaw near tip of snout, second one on right side and first and third on left side depressible, the others immovable; a pair of canines near symphysis of lower jaw; lateral teeth on jaws conical, those on lower jaw much larger and more widely spaced than those on upper jaw; no teeth on vomer or palatines. Interorbital shallowly concave, its least width equal to diameter of eye.

Lateral line inserted above angle of gill opening, bifurcating slightly behind vertical from base of fourth dorsal spine; lower branch abruptly curved backward and downward from bifurcation, to run along middle of body to base of middle caudal ray; upper branch coursing directly backward near dorsal to below a point slightly before penultimate dorsal spine, where it suddenly curves downward and ends immediately before reaching lower branch (Fig. 1B). Posterior part of body covered with minute scales, which occupy an area of rather indefinite extent, extending from base of caudal forward to slightly beyond vertical from base of last dorsal spine.

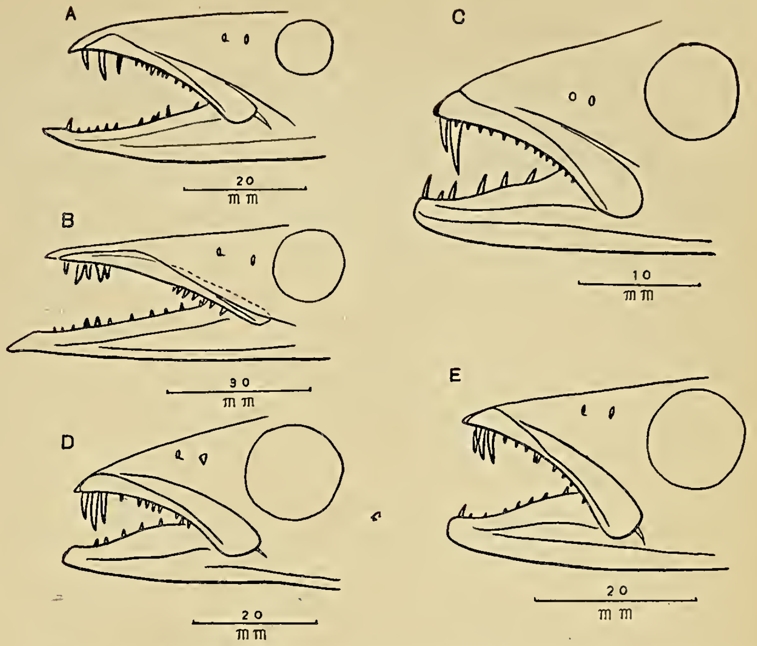

FIG. 5. Anterior portion of head of five species of Gempylidae, showing form of snout and extension of anterior extremity of premaxillary. A, *Mimasea taeniosoma;* B, *Gempylus serpens;* C, *Neoepinnula orientalis;* D, *Rexea solandri;* E, *Promethichthys prometheus.* Drawn by authors.

Dorsal inserted above upper angle of gill opening; dorsal spines becoming progressively shorter posteriorly; last spine separated from soft dorsal, which is about as large as anal. Anal inserted below base of fourth dorsal ray; preceded by a single spine. Pectoral extending to below base of sixth dorsal spine. Ventral slightly shorter than pectoral; inserted somewhat behind base of pectoral. Caudal deeply forked, with subequal lobes.

Gill rakers (Fig. 2C) small, largely hidden under the skin; each usually with 3 to 4 cusps and armed with several spines, except the one at the angle, which is also small and is T-shaped, with only the distal part exposed; 1 or 2 small accessory rakers frequently interpolated.

Color in formalin dark brown, paler below; spinous dorsal blackish between first and fourth spines; other fins pale.

REMARKS: Our single specimen, the basis of the description and figures, differs from Kamohara's accounts of *Mimasea taeniosoma* in having somewhat fewer soft dorsal and pectoral rays (dorsal soft rays 17 to 18 and pectoral rays 14, according to the original description) and longer ventrals (3.8 to 3.9 in head in the type). Probably each of these differences will be found to be included within the range of fluctuation when a larger number of specimens has been examined.

GEMPYLUS Cuvier

Gempylus Cuvier (1829: 200—type *G. serpens* Cuvier).

As one of the characteristics of the monotypic genus *Gempylus*, earlier authors (Jordan and Evermann, 1896: 884; Barnard, 1927: 789; Fowler, 1936: 636; Smith, 1949: 310) have mentioned "lateral line single." In his description of *Gempylus serpens*, however, Fowler (1936: 637) wrote: "Lateral line double, begins opposite base of first dorsal spine; upper branch extends high along back to a point opposite anterior elongated dorsal rays, where it suddenly becomes incomplete; lower branch complete to caudal base." In our single specimen referable to this species the lateral line is also double, but the upper branch ends at the base of the last dorsal spine.

In their definitions of the genus, Jordan and Evermann (1896: 884) and Fowler (1936: 636) mentioned the ventrals as having a spine and five soft rays. In our single specimen, however, the ventrals are composed of a spine and four soft rays, as described by Fowler (1936: 636) for the species. Cuvier (1829: 200), Goode and Bean (1895: 202), Barnard (1927: 789), and Longley and Hildebrand (1941: 73) indicated that the ventral is reduced to a single spine, but it seems very probable that they overlooked the soft rays, which are so minute that they can hardly be seen without the aid of a lens (Fig. 6B).

Gempylus differs from the other genera of this family in the form of the gill raker at the angle of the arch: it is very small and triangular and only its tip is exposed, instead of being T-shaped and moderately or greatly exposed (Fig. 2D). The maxillary (Fig. 6A) is largely hidden under the infraorbital membrane, as in the trichiurids.

The sharply pointed snout terminates in a large conical cartilaginous process, which projects far beyond the premaxillaries (Fig. 5B).

The present genus seems to us to be a highly specilized offshoot of a line of genera which is represented in Japanese waters by *Neoepinnula*, *Epinnula*, and *Mimasea*.

Gempylus serpens Cuvier

Fig. 2D, 5B, 6

Gempylus serpens Cuvier, 1829: 200—based on *Serpens marinus* Sloane, 1707, "Voy. Jamaica," 1: 26, pl. 1, fig. 2; Cuvier, in Cuvier and Valenciennes (1831: 207); Günther, 1860: 352; 1873–75: 106, pl. 68, fig. B; Goode and Bean, 1895: 202, fig.; Jordan and Evermann, 1896: 884; Jordan, Tanaka, and Snyder, 1913: 122; Jordan and Jordan, 1922: 305; Barnard, 1927: 789; Fowler, 1928: 135; 1936: 636; 1938: 277; Howell Rivero, 1938: 185; Kamohara, 1940: 98, fig. 46; Longley and Hildebrand, 1941: 72; Fowler, 1944: 75, 295, 422, 463, 499, pl. 2, upper fig.; Smith, 1949: 311, fig. 864.

Lemnisoma thyrsitoides Lesson, 1830: 160; Jordan and Evermann, 1905: 179; Jordan and Seale, 1906: 228.

Gempylus thyrsitoides Fowler, 1938: 253.

Gempylus coluber Cuvier, in Cuvier and Valenciennes, 1831: 211, pl. 221; Günther, 1860: 353; Franz, 1910: 57.

MATERIAL DESCRIBED: No. 57, 488 mm. (552.5 mm.), Tokyo market, from Sagami Bay.

The only previous definite record of this rare fish from Japan is that of Franz.

D. XXVIII, I, 12+6; A. II, I, 11+6; P. 14; V. I, 4; Br. 7. Head 5.10 in body length; depth 15.75. Snout 2.20 in head; eye 5.64; interorbital 8.00 (bony width 8.80); upper jaw 1.92; depth of caudal peduncle 7.66; pectoral 2.00; ventral 22.80; longest (5th) dorsal spine 3.57; longest (2nd) soft dorsal

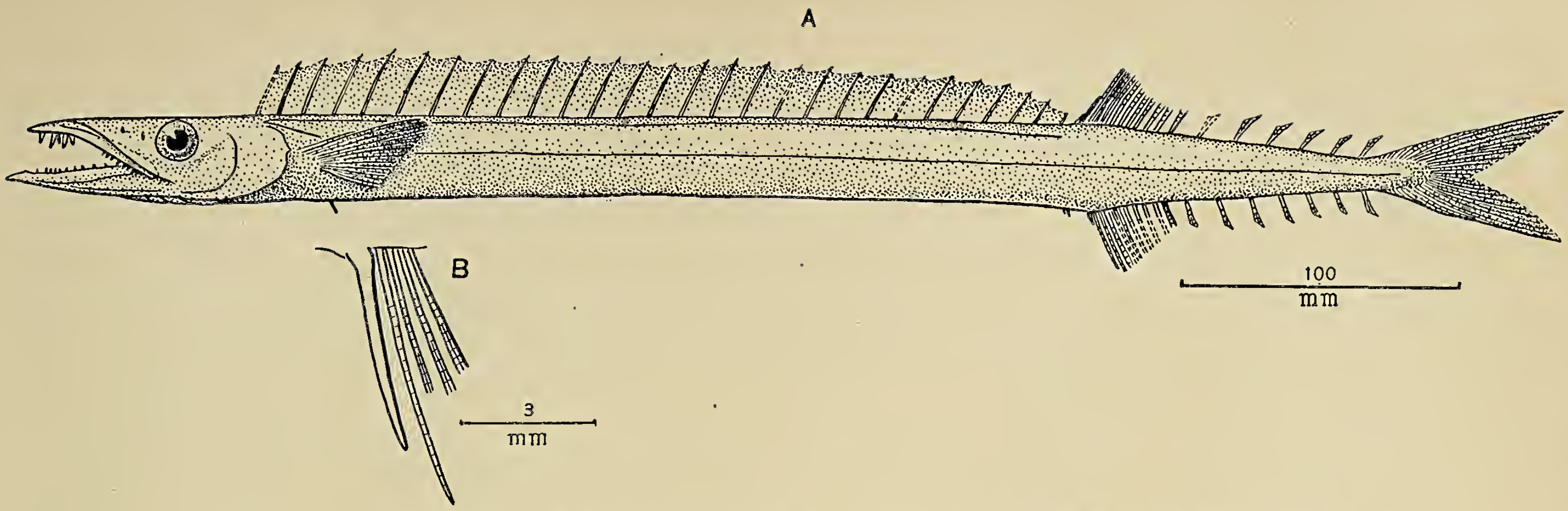

FIG. 6. *Gempylus serpens.* A, lateral view; B, ventral fin enlarged. Drawn by authors.

ray 3.57; longest (2nd) anal ray 4.26; caudal 1.57.

Body greatly elongated, strongly compressed, at its middle somewhat less than half as wide as deep. Snout (Fig. 5B) conical, acutely pointed, projecting far beyond premaxillaries; lower jaw also sharply pointed, extending far beyond tip of snout when mouth is closed, the distance between tip of snout and that of lower jaw about 2.30 in eye. Mouth large; maxillary largely hidden under the infraorbital membrane, extending to a little byond anterior edge of eye, its width about equal to least infraorbital space. Five fangs on upper jaw near tip of snout, 3 on left side and 2 on right; the anteriormost on each side and the hindmost on the left side depressible; lateral teeth of jaws large, conical, and widely spaced; palatine teeth small and weak, uniserial; face of vomer rather rough, but evidently edentulous. Interorbital flattish, much narrower than eye.

Two lateral lines both inserted below base of first dorsal spine; upper line running high to abrupt end below base of last dorsal spine; lower line descending gently backward and downward to tip of pectoral, then running along middle of body to base of caudal. Small scales scattered on basal part of caudal fin.

Origin of dorsal midway between eye and insertion of pectoral; base of spinous part of dorsal about 1.90 in body length; soft dorsal about as long as anal, inserted slightly in advance of first anal soft ray. Anal preceded by 2 minute isolated spines. Pectoral extending to below base of seventh dorsal spine. Ventral minute, inserted a little behind base of pectoral, with first soft ray much longer than either spine or other soft rays.

Gill rakers (Fig. 2D) small, mostly hidden under the skin; several much smaller ones set in a single series between the larger ones; both larger and smaller ones usually with a large basal plate and several small cusps.

Color in formalin uniformly dark brown, except for several small black spots scattered above base of pectoral. Fins all dark brown, with the margins somewhat darker.

REMARKS: The single specimen, the basis of our description and figures, agrees well with the published descriptions, except as noted under the genus and in having 28 instead of 29 to 32 dorsal spines and a slightly larger eye (5.64 in head instead of 5.8 to 7.0).

REXEA Waite

Rexea Waite (1911 [January 18]: 49—type *R. furcifera* Waite = *Gempylus solandri* Cuvier).

Jordanidia Snyder (1911 [May 6]: 527—type *J. raptoria* Snyder).

According to Whitley (1929: 120) the genus *Rexea* was first proposed by Waite on January 18, 1911, not June 24, 1911, as stated by Jordan (1920: 541). The genus *Jordanidia* Snyder was proposed on May 26, 1911, and, therefore, must give precedence to the earlier name of Waite.

Rexea solandri (Cuvier)

Figs. 5D, 7–9

Gempylus solandri Cuvier, in Cuvier and Valenciennes, 1831: 215.
Thyrsites solandri Günther, 1860: 352.
Jordanidia solandri McCulloch, 1915: 150; 1934: 81, pl. 34, fig. 300*a*.
Rexea solandri Whitley, 1929: 120, pl. 33, fig. 2; McCulloch, 1929: 269.
Thyrsites prometheoides Bleeker, 1856: 42; Günther, 1860: 352; Tortonese, 1939: 154.
Jordanidia prometheoides Schmidt, 1931: 41, fig. 5; Kamohara, 1938*a*: 50; 1938*b*: 20, fig. 8; 1940: 102, fig. 49.
Rexea furcifera Waite, 1911 (January 18): 49.
Jordanidia raptoria Snyder, 1911 (May 26): 527; 1912: 410, pl. 52, fig. 2; Jordan, Tanaka, and Snyder, 1913: 124; Kamohara, 1932: 148; 1934: 1199.

MATERIAL DESCRIBED: Nos. 1935, 1964, 1978, and 2124 (Matsubara's Collection), 101–242 mm. in standard length (119.5–290.5 mm. in total length), off Owase, Kumano-Nada, January 4–9, 1936; Nos. 2185 and 2186, 269 and 141 mm. (321 and 167 mm.), off Owase, December 25, 1935; Nos. 4100, 4102 to 4105, and 4260, 125–178 mm. (144–206 mm.), off Owase, January, 1939; No. 6234, 259 mm. (308.5 mm.), off Heta, Suruga Bay, March 26, 1939; No. 6785, 332.5 mm. (394 mm.), off Heta, November 22–24, 1938; Nos. 1185 and 1635, 100.5 and 168 mm. (115.5 and 200 mm.), Ensyu-Nada; Nos. 11934 and 11935, 162 and 139 mm. (196 and 169 mm.), off Kochi City, January, 1950.

D. XVII–XVIII, I, 15–16+2; A. I, 14–16 +2; P. 13 or 14; V. I or absent; Br. 7. Head 3.02 to 3.42 in body length; depth 3.81 to 7.35. Snout 2.42 to 2.60 in head; eye 3.97 to 4.76; interorbital 4.22 to 5.17 (bony width 5.80 to 6.80); upper jaw 2.13 to 2.44; depth of caudal peduncle 6.12 to 7.55; pectoral 1.97 to 3.14; longest (4th) dorsal spine 3.31 to 4.09; longest (3rd) dorsal ray 3.09 to 4.15; longest (3rd) anal ray 3.24 to 4.30; caudal 1.42 to 2.00.

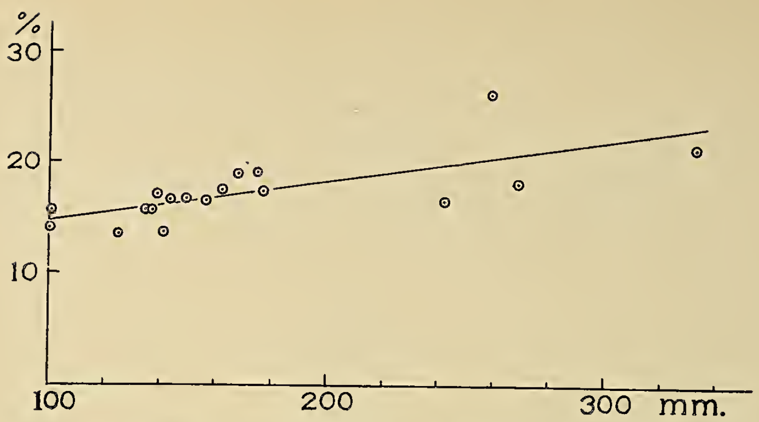

FIG. 7. Showing variation, with size, in depth of body in *Rexea solandri*. Proportional measurements (expressed in hundredths of standard length) are plotted against the standard length (mm.). Drawn by authors.

The 18 specimens vary greatly in proportions, especially in depth of body (Fig. 7), which gradually increases proportionally with size of the fish (standard length from 100.5 to 332.5 mm.). Body moderately elongated, deepest at the middle. In a specimen 259 mm. in standard length, however, the body is much higher than in the others (its depth is 263 thousandths of the standard length). Jaws conical; snout not projecting beyond the premaxillaries (Fig. 5D). Mouth large; maxillary not hidden under the infraorbital membrane, the extremity reaching slightly beyond anterior edge of eye or opposite anterior edge of pupil, its greatest width about twice the least infraorbital width. Fangs on upper jaw near tip of snout variable in number (Fig. 8); young fish smaller than 180 mm. in standard length typically having more than 3, usually 5 or 6, of which 3 are immovable and the others depressible; larger fish all bearing 3 immovable fangs; lateral teeth on jaws conical and widely spaced; a pair of canine-like teeth near the symphysis of lower jaw. Vomer edentulous; a single series of small teeth on palatines. Interorbital broadly and shallowly concave.

Lateral line inserted above upper angle of gill opening, bifurcating at or slightly before the vertical from base of fifth dorsal spine; upper line ending below middle of base of soft dorsal, lower one sometimes irregularly undulated on posterior part of body. Small

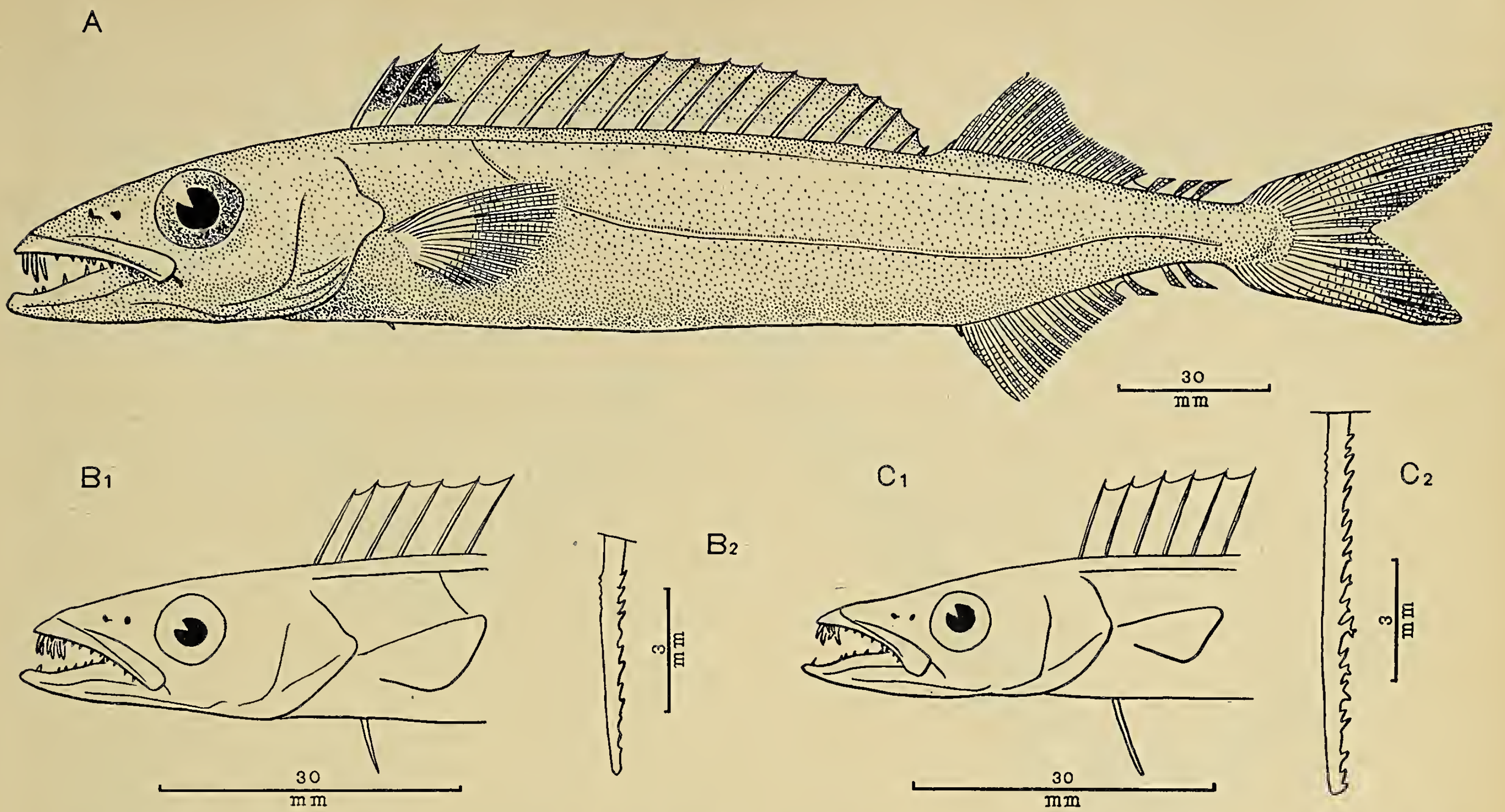

FIG. 8. *Rexea solandri*, showing variation, with size, in ventral fins and in number of fangs on upper jaw near tip of snout. A, No. 2124, measuring 242 mm. in standard length; B, No. 1935, 101 mm. long; C, No. 1936, much mutilated, smaller than preceding one. B_2 and C_2 showing ventral spines. Drawn by authors.

thin scales on posterior part of body only.

Soft dorsal and anal opposite, each preceded by a single spine and with last ray more or less remote from preceding one, but connected with it by a thin membrane. Pectorals extending to below base of sixth or seventh dorsal spine. Caudal deeply emarginated, with upper lobe the longer. Ventral fin absent or represented by a single spine; in specimens smaller than 242 mm. in standard length, spine always lying under middle of base of pectoral, as stated in original descriptions of *Gempylus solandri* and *Thyrsites prometheoides*. Spine with rather rough serrations along posterior margin and several much smaller ones along anterior edge near base (Fig. 8); variable in length and sometimes entirely hidden under skin, even in young specimens, but generally longer in younger ones, becoming shorter with growth of fish, finally becoming hidden under skin; entirely absent in specimens longer than 242 mm., as indicated in original description of *Jordanidia raptoria*.

Gill raker at angle of arch T-shaped, very long, and about two thirds exposed. Other rakers rather hidden under skin, each having large basal plate and several small cusps. In 2 smaller specimens, 100.5 and 101 mm. long, basal plate of each raker unarmed. Rarely, a minute accessory raker present between large ones (Fig. 9A). In larger specimens basal plates armed with many small spines and usually 2 or more armed accessory rakers interpolated (Fig. 9B–C).

Body in life bluish gray, paler below, with strong silvery luster. A large black blotch always present at anterior part of spinous dorsal.

REMARKS: In 1931, Schmidt demonstrated that *Jordanidia raptoria* Snyder is a synonym of *Thyrsites prometheoides* Bleeker, and more recently Kamohara (1938*a*: 50; 1938*b*: 20; 1940: 103) has confirmed Schmidt's opinion. We further conclude that the two species just mentioned are referable to *Gempylus solandri* Cuvier, described from New Zealand. As has already been mentioned, the body is slender and the ventral is represented by a single spine in the younger specimens, but the relative depth of the body gradually increases and

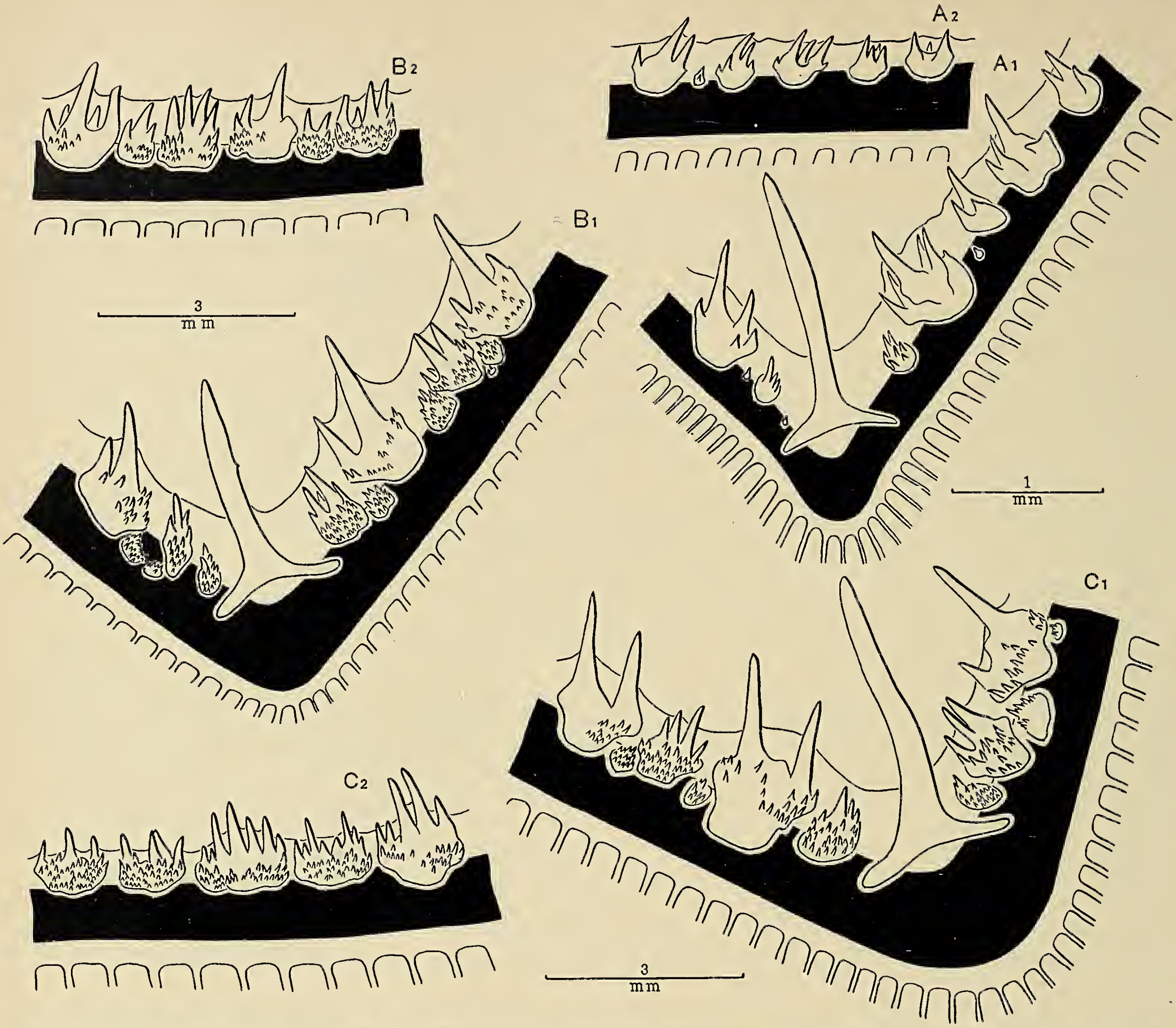

FIG. 9. Outer face of first gill arch in *Rexea solandri*, showing size variation of gill raker at angle of arch and o. rakers at middle part of lower branch. (Bony part of gill arch is black.) A_1 and A_2, right side, No. 1185, 100.5 mm. in standard length, provided with long ventral spine; B_1 and B_2, right side, No. 2124, 242 mm. in standard length, the largest one bearing ventral spine; C_1 and C_2, left side, No. 2185, measuring 269 mm. in standard length, lacking the ventral spine. Drawn by authors.

the spine becomes shorter with the growth of the fish, finally being hidden entirely under the skin. *Gempylus solandri* and *Thyrsites prometheoides* are described as having the body either moderately deep or rather slender (according to Günther, 1860: 352, the depth in total length is 5⅓ in the former and 7⅓ to 7¼ in the latter) and as having a single ventral spine, as in our younger specimens, whereas *Jordanidia raptoria* is said to have the body moderately deep (depth 5.0 in body length) and the ventral spine entirely lacking, as in our larger specimens. Whitley's (1929: pl. 33, fig. 2) illustration of *Rexea solandri* shows the body very deep (depth about 4.4) and the ventral absent, whereas McCulloch's (1934: pl. 34, fig. 300*a*) figure of *Jordanidia solandri* shows the body rather slender (depth about 5.4 in body length) and the ventral spine present.

McCulloch (1915: 151) distinguished *Jordanidia solandri* from *J. raptoria* by its smaller eye and broader interorbital. However, in comparing our specimens with the description of *Rexea furcifera* Waite (1911: 49), which has been understood by Australian ichthyologists to be a synonym of *Rexea solandri* or *Jordanidia solandri*, we fail to confirm these supposed differences (diameter of eye 4.8 and interorbital space 4.6 in head in *R. furcifera*).

In his description of *R. furcifera*, Waite mentioned "Ventral IV," but we think this is probably a misprint for "Ventral I."

Finally, we searchingly examined the descriptions of these four nominal species by various authorities and compared the other important characters as described with our specimens without finding any characteristics that would enable us to separate these species.

NEALOTUS Johnson

Nealotus Johnson (1865: 434—type *N. tripes* Johnson).

In general physiognomy, this genus closely resembles *Promethichthys* Gill but appears to differ in having a dagger-shaped spine behind the vent, followed by a minute spine; a straight lateral line; rather large nonimbricate scales; and a single short (dorsal) branch running upward and backward from each pore in the lateral line (Fig. 10A). *Promethichthys* lacks the isolated free spines behind the vent; its lateral line descends sharply downward and backward on the anterior part of the body (Fig. 1C); its scales are definitely imbricated and cover the whole body and head except for the snout, jaws, throat, and interorbital space; and each pore in its lateral line has short upper and lower branches running obliquely backward, except on the anterior curved part, where the pores have only an upper branch, as in *Nealotus* (Fig. 10B–C).

Nealotus tripes Johnson

Figs. 10A, 11, 12

Nealotus tripes Johnson, 1865: 434; Günther, 1887: 35; Goode and Bean, 1895: 199; Jordan and Evermann, 1896: 881; Smith and Pope, 1906: 465, fig. 1; Jordan, Tanaka, and Snyder, 1913: 123, fig. 89; Jordan and Hubbs, 1925: 221; Norman, 1930: 351, fig. 41; Fowler, 1936: 634; Kamohara, 1940: 99, fig. 47.

MATERIAL DESCRIBED: No. 13957, 199 mm. in standard length (237 mm. in total length), off Owase, Kumano-Nada, October 2, 1950.

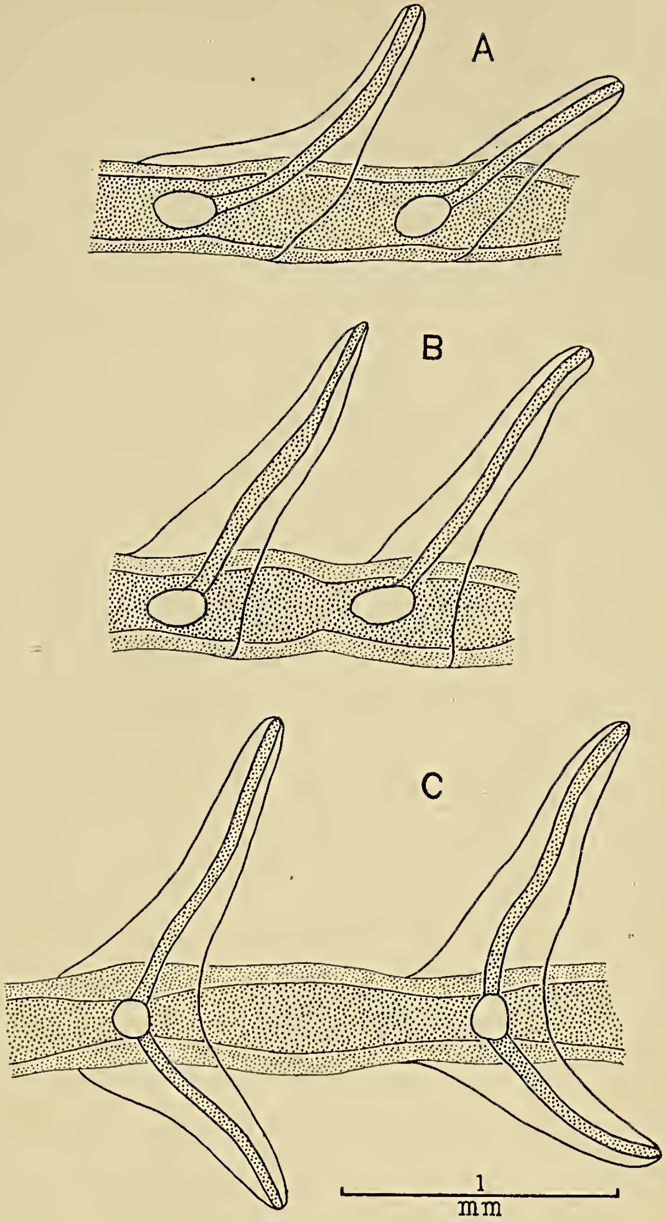

FIG. 10. Lateral line in two species of Gempylidae. A, anterior part in *Nealotus tripes;* B, curved part in *Promethichthys prometheus;* C, anterior section behind curved portion in *P. prometheus*. Drawn by authors.

Originally described from one specimen taken at Madeira, this species has since been reported as follows: one specimen each from between the Bahamas and Madeira (Günther), from near Hamashima, Japan (Smith and Pope), and from near Misaki, Japan (Jordan and Hubbs); and two specimens from off the west coast of middle Africa (Norman).

D. XX, I, 17+2; A. II, I, 16+2; P. 12; V. I; Br. 7. Head 3.56 in body length; depth 6.63; width 12.75. Snout 2.43 in head; eye 5.00; interorbital 5.18 (bony width 5.65); upper jaw 2.03; depth of caudal peduncle 5.53; pectoral 1.75; ventral 12.15; longest (5th) dorsal spine 3.63; longest (4th) dorsal soft ray 3.27; dagger-shaped spine behind

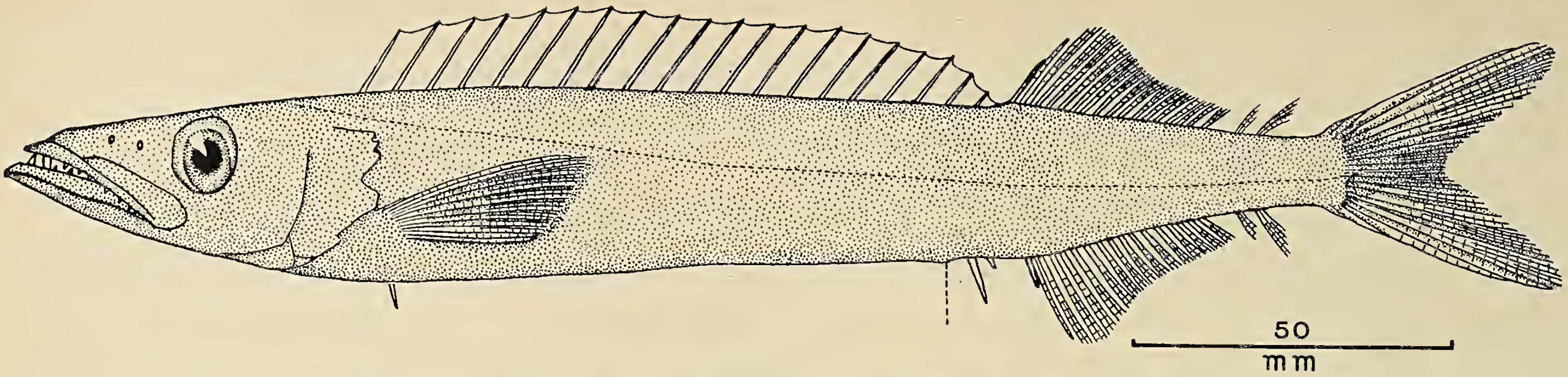

FIG. 11. *Nealotus tripes* (No. 13957). Drawn by senior author.

vent 8.22; longest (2nd or 3rd) anal soft ray 3.75; caudal 1.41.

Body very elongate and compressed, width anteriorly about half the depth. Upper profile of head nearly straight from tip of snout to insertion of dorsal fin. Snout slightly more than twice as long as eye, not projecting beyond premaxillaries. Jaws bluntly conical; lower jaw projecting beyond tip of snout a distance equal to one third diameter of eye. Mouth large; maxillary exposed, extending to below front edge of pupil, about 4 times as broad as least infraorbital width. Three fangs on each side of upper jaw near tip of snout, second one on right side and first and third on left depressible, but others immovable; a pair of canines near symphysis of lower jaw, entirely exposed immediately in front of closed mouth; lateral teeth on jaws conical and widely spaced, those on lower jaw rather larger than those on upper. Vomer edentulous; a single series of small teeth on palatines. Eye round, nearly entering upper profile of head, slightly less than half as long as snout; infraorbital very narrow, its least width about half that of pupil; interorbital space slightly narrower than eye, with 4 low longitudinal ridges; space between inner pair of ridges shallowly concave. Angle and lower edge of preopercle armed with several vestigial spines, invisible without aid of a lens. Border of opercle shallowly notched between 2 obtuse projections.

Lateral line single, inserted slightly before perpendicular through preopercular margin and running straight backward and slightly downward to base of caudal fin; each pore in lateral line bearing a short branch, enclosed in a broad sheath and running backward and upward. Scales rather large, nonimbricate, scattered here and there on surface of head and body.

Dorsal fin inserted midway between tip of opercle and upper end of gill opening, much nearer insertion of pectoral than posterior border of eye; base of spinous dorsal a little more than 3 times as long as base of soft dorsal and about one-half length of body, excluding caudal fin; soft dorsal about as long as anal, preceded by a single spine and inserted slightly in advance of first anal soft ray. A flat dagger-shaped spine, little more than half as long as eye, located slightly behind vent; a small spine, hardly visible with naked eye, behind dagger-shaped spine. Soft anal inserted under third ray of soft dorsal and preceded by a spine; finlets 2 in dorsal and in anal. Pectoral rather long, extending to slightly beyond vertical from base of seventh dorsal spine; lower pectoral rays not especially shortened. Ventral reduced to a single smooth spine, about as long as pupil, inserted below middle of base of pectoral fin. Caudal deeply emarginated, with subequal lobes.

Gill raker at angle of arch T-shaped, very long, with somewhat more than half its entire length exposed; other rakers with a large roundish basal plate, armed with 3 or 4 sharp cusps and, usually, 1 to 3 small accessory spines; a minute accessory raker, armed with 1 to 3 small spines, interpolated between pairs of larger ones (Fig. 12).

In fresh state prior to preservation, head and body jet-black; pectoral and basal part

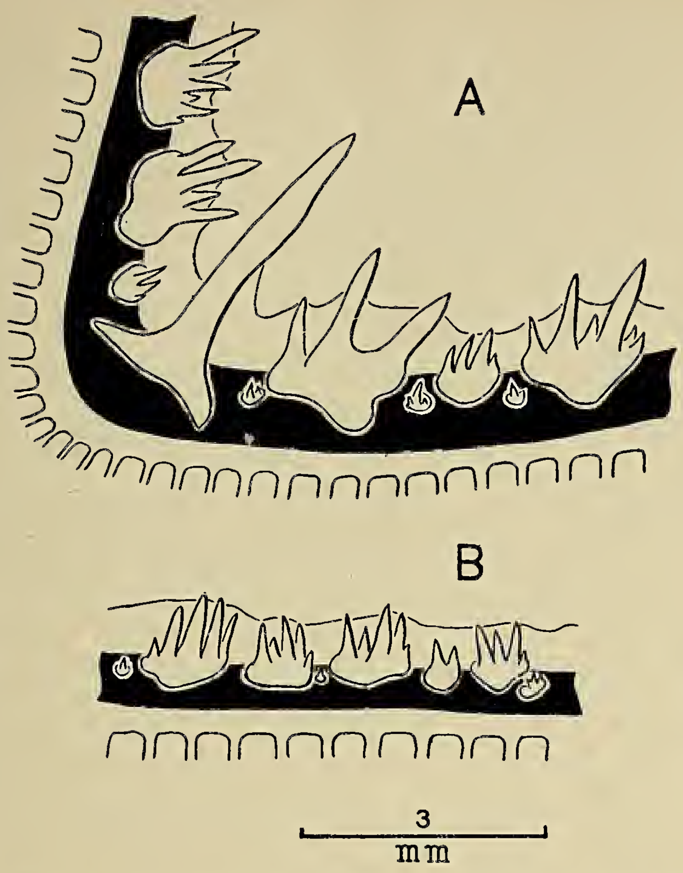

FIG. 12. Outer side of first gill arch in *Nealotus tripes*. A, region near angle on right side; B, middle portion of lower branch on right side. Drawn by authors.

and membranes of caudal dark brown; other fins entirely pale. After preservation, head and body somewhat paler. Buccal and branchial cavities and peritoneum jet-black.

REMARKS: In our specimen a minute spine can be seen with the aid of a lens immediately behind the dagger-shaped spine in front of the anal fin. This spine has hitherto been overlooked. A spine preceding the soft dorsal and the anal has been misinterpreted as a soft ray by most earlier authors. Our specimen differs from the type description of this species in having a deeper body, a longer snout, and fewer dorsal and anal soft rays (the type was described as having depth 9½ in total length, eye 1⅔ in snout, dorsal XXI, 19+2, and anal 18+2). Günther's specimen was only 33 mm. long and naturally differs in many points from our adult female. Our specimen is the size of Smith and Pope's specimen but has smaller eyes and fewer dorsal and anal soft rays (eye 1.6 in snout and 4.3 in head, dorsal XXI, 19+2 and anal I, 18+3 in the latter). In general our specimen agrees well with Norman's description, except in having a deeper body, a larger head, and smaller eyes (depth 8 to 8⅔ in length of body, head nearly 4 in length of body, and eye 4¼ to 4½ in length of head, according to Norman).

Not having examined specimens of this species, Tanaka and Kamohara both synonymized it with *Promethichthys prometheus* without giving any sound basis for their action. This species is sharply distinguished from *Promethichthys prometheus*, not only in the generic characters indicated above and in the key, but also by having a greater number of spines in the first dorsal (20 or 21 instead of 18), by the more posterior position of the ventral spine (inserted below middle of base of pectoral fin instead of ahead of anterior end thereof), and by detailed characters of the gill rakers on the first arch (the bony part of the gill arch is armed with minute accessory rakers interpolated between pairs of larger ones, instead of being rather thickly covered with many small accessory rakers, and the raker at the angle is very long, with somewhat more than half, instead of about one third, of its entire length exposed).

PROMETHICHTHYS Gill

Promethichthys Gill (1893: 115, 123—type *Prometheus atlanticus* Lowe = *Gempylus prometheus* Cuvier).

Promethichthys prometheus (Cuvier)

Figs. 1C, 2B, 5E, 10B–C

MATERIAL DESCRIBED: No. 4101, 185 mm. in standard length (211.5 mm. in total length), off Owase, Kumano-Nada, January, 1937; No. 1551, 261.5 mm. (311 mm.), Ensyu-Nada; Nos. 11932 and 11933, 215.5 and 197 mm. (258.5 and 235 mm.), off Kochi City, January, 1950.

Fangs on upper jaw near tip of snout 4 to 6, of which 3 are immovable and the others depressible. Scales small and definitely imbricate, evident over entire body and head except on snout, jaws, throat, and interorbital.

Lateral line with a row of larger scales, extending far beyond base of middle caudal ray. Ventrals (Fig. 1C) always represented by a single spine, becoming shorter with the growth of the fish (in the smallest one, measuring 211.5 mm., the spine being 1.23 times as long as eye, and anterior edge armed with a row of minute and blunt spines).

Gill rakers moderately large but mostly hidden under skin (as in other species of this group), each tricuspid and armed with several small spines, except for one at angle, which is T-shaped and about one third exposed; bony part of gill arch rather thickly covered with small accessory circular rakers, which are densely covered with small prickles (Fig. 2B).

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Monograph of the Genus *Isodendrion* (Violaceae)
Hawaiian Plant Studies 21[1]

HAROLD ST. JOHN[2]

INTRODUCTION

History

The taxonomic history of the genus *Isodendrion* is brief. It was described by Asa Gray in 1852, being based upon the three new species, *I. pyrifolium*, *I. longifolium*, and *I. laurifolium*, collected by the United States Exploring Expedition on Oahu, Sandwich Islands. Later, Gray gave a fuller account of the same three species (1854: 92–96) and illustrated two of them (1856: Atlas, pl. 8–9).

Horace Mann, Jr., and W. T. Brigham did not find any of the species during their exploration in 1864 and 1865, and Mann's account in his incipient "Flora of the Hawaiian Islands" (1866: 121–122) followed the treatments by his professor, Asa Gray.

Hillebrand (1888: 18–19) gave a good treatment, with a key and lengthy descriptions. The several more recent collections by himself and his associates were all identified with the three species published earlier by Gray. Hillebrand added no other species.

A fourth species, *I. subsessilifolium*, was discovered and described by Heller (1897: 856–857, pl. LIV) from the island of Kauai.

MacCaughey gave a summarized account of the Hawaiian Violaceae and included *Isodendrion* (1918: 9–11). He stated that his paper was "the first comprehensive account which has included all of the recorded species and varieties. It is based upon field work extending over nearly ten years and contains new ecological material." However, this paper added nothing to the knowledge of *Isodendrion*. It copied word for word, or with slight paraphrasing, the treatment given by Hillebrand (1888: 18–19). Although the paper by Heller is included in his bibliography, MacCaughey makes no mention or disposition of Heller's very distinct and well-described and illustrated species from Kauai, *I. subsessilifolium*.

Relationship

Gray, in describing the genus (1852: 324, and 1854: 93), emphasized that the flowers were regular, both calyx and corolla, and the stamens are so illustrated, but with "the *unilateral stigma*, which, in a *flower otherwise perfectly regular*, vindicates the relationship with the genuine *Violeae*." He also indicated the stamens as entirely separate, and "*destitute of any prolongation of the connective* . . ." He concluded that it was a member of the section Alsodineae and related to *Alsodeia*, *Paypayrola*, and *Pentaloba*.

Bentham and Hooker (1862: 115–119), not having seen any specimens of the genus *Isodendrion*, obviously relied heavily on Gray's

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[1] This is the twenty-first of a series of papers designed to present descriptions, revision, and records of Hawaiian plants. The preceding papers have been published in Bernice P. Bishop Mus., Occas. Papers 10(4), 1933; 10(12), 1934; 11(14), 1935; 12(8), 1936; 14(8), 1938; 15(1), 1939; 15(2), 1939; 15(22), 1940; 15(28), 1940; 17(12), 1943; Calif. Acad. Sci., Proc. IV, 25(16), 1946; Torrey Bot. Club, Bul. 72: 22–30, 1945; Lloydia 7: 265–274, 1944; Pacific Sci. 1(1): 5–20, 1947; Brittonia 6(4): 431–449, 1949; Gray Herb., Contrib. 165: 39–42, 1947; Pacific Sci. 3(4): 296–301, 1949; Bernice P. Bishop Mus., Occas. Papers 20(6): 77–88, 1950; and Pacific Sci. 6(1): 30–34, 1952.

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detailed and illustrated account. They placed it in the tribe Paypayroleae which had unarmed connectives and subequal petals, and put it next to the genus *Paypayrola*.

The most recent tribal placement of *Isodendrion* is by Melchior in the second edition of the "Pflanzenfamilien" (1925: 347, 355–356). As was natural, he also relied heavily on Gray's original description of the genus and two folio illustrations, but Melchior also saw and dissected a specimen of *I. laurifolium* Gray and printed the first figure of its stamen showing a terminally apiculate connective. His generic description is largely a German translation of Gray's, but he adds, correctly, that the three placentae bear each 2–4 ovules (1925: 355). He also adds, incorrectly, "Stam. [ina] mit freien oder ganz am Grunde zu einem sehr niedrigen Ring verwachsen, flachen Filamenten . . . Nektarorgane auf dem Rücken der Filamente fehlend oder in Form von Schuppen in ihrer ganzen Länge den Filamenten angewachsen. . . . Blüten . . . grünlich-weiss oder rötlich . . ." After dissecting the flowers of two of the three genuine species known to Melchior (the type of *I. longifolium* having already vanished) and of the 11 additional species here described, no factual basis is seen for his statements that the stamens sometimes arise from a low, joined filament ring; that the staminal nectaries may be dorsal scales growing on the full length of the filaments; or that the flowers are ever reddish. Léveillé stated no flower color. Gray had surmised that the petals of *I. pyrifolium* and *I. longifolium* were probably white; and Hillebrand stated for his composite *I. pyrifolium* that the petals were greenish white. Yet MacCaughey (1918: 10) stated in his compilation that *I. longifolium* had the flowers "purplish-white." He left no specimens of this or any other *Isodendrion*, and no confirmation of his statement is known. Melchior's statement that some flowers were reddish may have been a free translation of MacCaughey's "purplish-white." He places *Isodendrion* in the subfamily Violoideae, the tribe Rinoreeae, and as the single genus in the subtribe Isodendriinae. The other members of the tribe (*Rinorea*, pantropic; *Allexis*, African; and *Gleospermum*, tropical American) all differ fundamentally in having produced, elaborate connectives and the stamens mostly connate into a filament tube.

During detailed dissection and illustration of the flowers of all the species, several corrections have been made in the generic characters of *Isodendrion*. The flowers are always zygomorphic and single. The sepals are distinct and unequal. The petals unequal, the lower being longer and larger than the lateral, and the lateral longer and larger than the upper pair. The distinct stamens (never in any way united) are unequal in size, and all the stamens, or the two distal ones, are apically aculeate or at least apiculate (in *I. pyrifolium*) by a prolongation of the connective. Several of the species have a swollen gland borne dorsally on the filaments. The plants are shrubs, not trees.

Though the flowers of *Isodendrion* are definitely irregular and have a violet-like appearance, the lower petal lacks any spur or saccate enlargement, hence the genus cannot be placed in the tribe Violeae and must remain in the tribe Rinoreeae. Because of the significance of the staminal characters, it does not show close relationship to and should be kept distinct from the subtribes Rinoreinae and Paypayrolinae. It is much closer to the Hymenantherinae, which differs from the Isodendriinae by having the fruit a berry, the sepals connate at base, the petals sessile, and the stipules deciduous. It has strong resemblances in this subtribe to the genus *Melicytus*, containing four species of shrubs and trees from New Zealand, the Kermadec, Norfolk, and Fiji Islands. In *Melicytus*, however, the flowers are dioecious; the stamens almost sessile; ovary with 3–5 many-ovuled placentae; stigma 3–5-lobed; and stipules deciduous. These characters distinguish it clearly. However, it is close to *Isodendrion* in having the stamens free; the connective produced into a scale or prickle and with a dorsal honey gland at the base; and flowers axillary, solitary, or in few-flowered fascicles.

It is agreed that Melchior had good reason for placing *Isodendrion* alone in a distinct subtribe, but he implied by his placement in his natural key that it was related most closely to the subtribe Rinoreinae. For the reasons given above, we disagree in this. Rather, it seems most closely related to *Melicytus* in the Hymenantherinae.

Parenthetically, the comment can be made that although Melchior (1925: 355–356) lists, as the important special literature, the treatments by Gray, Hillebrand, Léveillé, and MacCaughey, he, too, omits the one by Heller and his very distinct species *I. subsessilifolium*. Melchior accepts only the three original species of Gray and *I. Fauriei* Lévl., oblivious of the fact that the latter is based on a specimen of a well-known species of *Gouania* (Rhamnaceae).

Distribution

The 14 species of *Isodendrion* are distributed unequally between the larger Hawaiian islands. Luckily all of the collections include the name of the island in the data, even though two thirds of the collections were made before 1871. Such records cannot be placed precisely on a map. However, each is shown on the map (Fig. 15) by a circle on a likely part of the island. The precise localities known for the more recent collections are indicated by black discs. For the island of Maui, the evidence has vanished. Hillebrand (1888: 18) listed two of his own collections from Olowalu and Wailuku. These are believed to have been destroyed in the bombing of Berlin in 1943. No duplicates of these two numbers have been found in any other herbaria, so the Maui records are now lost. In 1914 Rock found a single Maui sheet in the Berlin Herbarium, with the data "S. ridge of Wailuku Valley, West Maui, Aug. 1870, Oloalu ? or Valley of Waihee." He noted that the leaves from the Waihee, West Maui, plant are much larger than the others. There is no record from the now-denuded island of Kahoolawe. *Isodendrion* has been found on all the other large Hawaiian islands. Kauai has three species, Niihau one, Oahu six, Molokai one, Lanai one, and Hawaii two. It will be seen that the largest numbers are on Oahu and Kauai, and that the three northernmost islands—Kauai, Niihau, and Oahu—have 11 of the 14 species. The larger northern islands are considered to be of greater geologic age than the others.

Zonation

The vegetational zones are well marked in the Hawaiian Islands, and it is of interest to consider the zonation of any new species. For the species *I. hawaiiense*, *I. lanaiense*, *I. Lydgatei*, *I. molokaiense*, and *I. Remyi*, there is no zonal information, due to the lack of precise locality data. The vegetational zones of Ripperton and Hosaka (1942) are used here. In Zone B is the locality for *I. Hosakae*, and probably that of *I. Lydgatei.* In Zone C 1, are the stations for *I. Forbesii*, *I. laurifolium*, *I. longifolium*, *I. pyrifolium*, *I. subsessilifolium*, and *I. waianaeense*. In Zone D 1 is the station for *I. maculatum*, which is at an elevation of 800 feet in woods in the deep narrow gulch of Hanakapiai on the moist windward coast of Kauai. The others, listed above for Zones B and C 1, are in a region of dry scrub probably once forested with an open dry forest or in the slightly higher localities that are still covered with a dry forest. These lowland, or "kula," lands were overrun by feral cattle soon after 1782 and, as a result, the native forest was largely destroyed. During the last two or three generations, cattle pasturing has been controlled, but on these semiarid lower slopes and ridges the grazing has been continuous and heavy. Grazing during these two periods has resulted in the almost complete destruction of the plant species native to these lowland regions.

The rarity of the species of *Isodendrion* is a result of this overgrazing. This can be demonstrated statistically. The only collectors to find more than one species were Pickering and Brackenridge (collecting in 1840), Rémy (in 1851–1855), and Hillebrand (1850–1871). Of the 14 species, only 3 have been collected more than once (not counting the revisit by the same collector, Hosaka, to the known type locality of *I. Hosakae*). Since 1872 there have been only five collections of *Isodendrion*, by five different collectors, representing four species. Other botanists who have collected widely in the islands, as Rock, Skottsberg, Fosberg, Mitchell, Cowan, Webster, Wilbur, *et al.*, have failed to find the genus. In a sense this revision of *Isodendrion* has almost been a study in paleontology, as the investigation has been almost wholly of old collections in herbaria of species now extinct. It would have been gratifying to have many and abundant collections for each species. Such has not been the case. Though Hillebrand and others have grouped under *I. pyrifolium* any collection with more or less ovate leaves, it has been learned from study of the flowers, fruits, and stipules that there has been much speciation resulting in narrow endemism. No species is known to occur on more than one island, and, furthermore, there is local endemism to a particular mountain range or even to a few adjacent mountain valleys, as is so characteristic among the older Hawaiian plant genera. Since the best characters are in the flowers and stipules, it is very helpful to find that the stipules are long persistent and that the perianth is marcescent and persistent even on mature fruits. These characteristics have made it much easier to study and understand the species of *Isodendrion*.

Extinction of the Species

One cannot always prove that a given species of plant is extinct in its natural habitat, but the data presented in the discussion of distribution show that there is a great probability that the majority of the known species of *Isodendrion* are extinct, as well as the one or two probably lost species from Maui, once recorded by Hillebrand. Of the 14 known species, nearly two thirds have not been collected since 1871 and are assumed to be extinct. The remaining species have been found and collected between 1895 and 1950, and most of these are probably extant, two of them having been found two and three times. These living species are: *I. Forbesii*, *I. maculatum*, and *I. subsessilifolium* of Kauai; *I. waianaeense* of Oahu; and *I. Hosakae* of Hawaii.

Phylogeny

As is indicated by the arrangement in the key, the species fall into two groups. The first one has glabrous sepals, petals, and stipules. It appears that this is the group of more primitive species. The fully glabrous ones are only three, *I. laurifolium* and *I. longifolium* of Oahu and *I. maculatum* of Kauai. These all have elongate, more or less oblanceolate blades. There is little basis for choice between these, but it is suggested that *I. laurifolium* represents the most primitive species.

The group of really hairy species, which is considered more advanced, contains three species on Oahu, two on Hawaii, and one each on Niihau, Molokai, and Lanai.

Acknowledgments

Although parts of this study were done while visiting other herbaria, the bulk of it has been accomplished in Honolulu through the generous loan of herbarium specimens. With cordial thanks, acknowledgment is made of loans from the United States National Herbarium, Washington; the Gray Herbarium, Harvard University, Cambridge; the Royal Botanic Gardens, Kew; the Museum National d'Histoire Naturelle, Paris; and the Herbier Barbey-Boissier, Geneva.

Explanations

The location of the specimens studied and cited is indicated by the standard abbreviations (Lanjouw, 1939). The great majority of the specimens are in the following:

BISH = Bernice P. Bishop Museum, Honolulu. All specimens not otherwise assigned are in this collection.
GH = Gray Herbarium, Cambridge.
P = Museum National d'Histoire Naturelle, Paris.
US = United States National Herbarium, Washington.

The maturity or completeness of the specimens cited is indicated in a following parenthesis by the following abbreviations:

b. = bud
fl. = flower
fr. = fruit
i. = immature
lf. = leaf
st. = stem

TAXONOMY

Family *VIOLACEAE*

Genus Isodendrion Gray

Am. Acad. Arts Sci., Proc. 2: 324–325, 1852; U. S. Exploring Exped., Botany, Phanerogamia 15: 92–93, 1854; Atlas pl. 8–9, 1856.

Shrubs; stems mostly branching, woody, the bark roughened by the long persistent indurate subtriangular stipules; leaves alternate, short petioled; blades chartaceous to subcoriaceous, from linear lanceolate to elliptic, oblanceolate, or ovate, the margins toothed towards the apex; inflorescence axillary (a reduced cyme), of a single peduncle bibracteolate at apex, bearing a single 1-flowered pedicel; flowers fragrant; sepals 5, unequal, persistent, more or less lance-ovate, glabrous or pubescent, the margins thin, glabrous or ciliate, overlapping at base; corolla clearly irregular; petals 5, greenish or whitish, the lower two thirds being a ligulate claw, the upper third a broader, more or less oval limb, the claws laterally imbricate, the uppermost exterior, the lower petal interior, the whole imitating a corolla tube, particularly the lower petal and less so the others have the upper half of the claw and at least the base of the limb fleshy, thickened, rigid and channel-like; petals and stamens marcescent, persisting around the fruit; stamens 5, unequal or subequal, free on the receptacle; filaments ligulate, with or without a dorsal enlarged nectar gland; anthers oblong to ovate or subsagittate, the two sacs oblong, dehiscing by a longitudinal medial suture; connective in all the stamens or at least in the lower ones produced into a terminal mucro, flap, or prickle, which is usually incurved; ovary glabrous, 1-celled, with 3 placentae bearing 2–4 orthotropous ovules; style glabrous, filiform, gently sigmoid, the apex decurved and enlarged; stigma oblique, deflexed, excavate; capsule ovoid, beaked, deeply 3-lobed by longitudinal furrows, cartilaginous, prominently veined, 3-valved; seeds commonly 2 to each valve, obovate, smooth, shining, the apex truncate and excavate; embryo axile; the 2 cotyledons opposite, oval, free in an ample cavity but surrounded by the abundant endosperm.

Fourteen species of the Hawaiian Islands.

KEY TO SPECIES

A. Sepals glabrous on the midrib; petals glabrous (except in *I. Forbesii*); stipules glabrous on the midrib or central strip (and in some species on the margin also); well-developed leaves 5–23.5 cm. long; leaves glabrous,
  B. Sepals glabrous throughout,
    C. Stipules glabrous; blades oblanceolate,
      D. Stipules 2.5 times as long as wide; blades 2.2–9.2 cm. long; anthers nearly oblong in outline . . . . 6. *I. laurifolium*
      D. Stipules less than 2 times as long as wide; blades 6.5–22 cm. long,
        E. Lower petal 10 mm. long; stamens not apiculate; leaf margin obscurely undulate . . . . 7. *I. longifolium*

E. Lower petal 6 mm. long; apex of connective apiculate; leaf margin distinctly serrulate..........9. *I. maculatum*
C. Stipules ciliate; sepals 3-nerved, thin; blades elliptic or oblong-oblanceolate,
F. Lower petal 10.5 mm. long; leaf margins entire or subsinuate; anther acicular mucronate on apex of connective..........14. *I. waianaeense*
F. Lower petal 12.5 mm. long; leaf margin sinuate-denticulate; anther umbonate on apex of connective..........13. *I. subsessilifolium*
B. Sepals ciliolate; stipules glabrous on the back,
G. Stipules ciliolate generally; filaments with a distal oblong-oblanceolate gland; petal limb glabrous; blades 5–9 cm. long..........8. *I. Lydgatei*
G. Stipules glabrous; filaments glandless; petal limb ciliolate; blades 3.3–15 cm. long, elliptic to oblance-elliptic..........1. *I. Forbesii*
A. Sepals and stipules pubescent on midrib or central strip and ciliate; petals pilose without; leaves 1–6.5 cm. long, pubescent at least below,
H. Blades narrowly elliptic,
I. Lower petal 14–18 mm. long; lateral petals symmetric; anther with strong, ascending prickle; blades serrate, acute..........4. *I. Hosakae*
I. Lower petal 12 mm. long; lateral petals asymmetric; anther with minute reflexed mucro; blades crenate, obtuse..........3. *I. Hillebrandii*
H. Blades obtuse, ovate or lance-ovate or oblong-oblanceolate or elliptic,
J. Blades lance-ovate; filament glandular on the distal side, cruciform at apex..........2. *I. hawaiiense*
J. Blades ovate or widest at or above the middle; filament not cruciform or glandular (except in *I. molokaiense*),
K. Filament with a distal gland; lateral petals with claw with 5 nerves, unbranched from base to apex and the limb broad ovate; sepals 4–4.6 mm. long; lower petal 10 mm. long..........10. *I. molokaiense*
K. Filament glandless,
L. Blades ovate, the margins serrulate; stipule midnerve pubescent,
M. Limb of lateral petals linear-elliptic, the claw 5-nerved to the apex; sepals 4–5 mm. long..........12. *I. Remyi*
M. Limb of lateral petals ovate or oval, the claw 3–5-nerved at base, these nerves soon forking; sepals 3–4.1 mm. long,
N. Lower petal 11 mm. long; petals unequal in length; stipules ovate or asymmetrically so; bundle scar 1..........5. *I. lanaiense*
N. Lower petal 8 mm. long; petals subequal in length; stipules deltoid; bundle scars 3..........11. *I. pyrifolium*
L. Blades elliptic or oblong-oblanceolate, the margins undulate; stipules glabrous on the back..........14. *I. waianaeense*

1. ***Isodendrion Forbesii*** sp. nov.

ILLUSTRATIONS: Figure 1.

DIAGNOSIS TYPI: Frutex ad 8 dm. alto, ramis 3–4 mm. diametro cortice nigro-fusco transverse asperrato et longitudine sulcato, cicatricibus 0.8–1.5 mm. lato lunato-ovalibus pallidibus, fasciculis 3, ramulis foliferis 1.5–7 cm. longis cum 5–13 foliis adscendentibus 1.5–2.5 mm. diametro glabris rubescentibus vel viridibus a stipulis persistentibus asperratis, nodis 1–8 mm. plerumque 3 mm. distantibus, stipulis 2.5–3.1 mm. longis 1.3–1.5 mm. latis anguste oblique deltoideis vel oblongo-deltoideis glabris carina valde in-

crassata basi incrassato, petiolis 1–6 mm. longis validis subnigris deinde pallidioribus et suberiferis, laminis 3.3–15 cm. longis crassis subcoriaceis valde elevato-reticulatis ellipticis vel oblanceo-ellipticis plerumque obtusis cuneatis marginibus minime undulato-crenulatis nervis secundariis in uno latere 8–10 adscendentibus arcuatis sinuatis confluentibus, floribus solitariis axillaribus, pedunculis ad 1 mm. longis ad apicem bibracteolatis, bracteis 1.5 mm. longis ovatis acutis glabris, pedicelis 2–3 mm. longis glabris, sepalis 3.2–3.7 mm. longis 1 mm. latis anguste oblongo-lanceolatis membranaceis perspicuis albis vel minime viridibus 5- vel plurimi-nervosis glabris praeter marginibus sparse ciliolatis apice plano nigro-fusco, petalis irregularibus unguibus lateraliter imbricatis tubo imitans, petala inferiore (postquam bullanda) 6.2 mm. longa, ungue 4.5 mm. longo 1.5 mm. lato 3-nervoso elliptico-ligulato ad basem membranaceo ad apicem incrassato, limbo 2.1 mm. longo 1.3 mm. lato ciliolato obovato carnoso non pellucido canaliculato apice subacuto, petalis lateralibus 6.3 mm. longis unguibus 3.9 mm. longis 1.2 mm. latis elliptico-ligulatis membranaceis 3-nervatis, limbis anguste ellipticis ciliolatis carnosis 3-nervatis, petalis superioribus 6.2 mm. longis, unguibus 4.2 mm. longis elliptico-ligulatis membranaceis 3-nervatis, limbis 2 mm. longis 0.9 mm. latis anguste oblongo-ellipticis ciliolatis, staminibus subaequalibus inferis 2 mm. longis, filamentis 0.8 mm. longis ligulatis, antheris 1.2 mm. longis 0.5 mm. latis anguste ellipticis subsagittatis, connectivo mucronato, ovario 1.2 mm. longo ovoideo longitudinaliter 3-lobato, stylo 3.6 mm. longo subulato, stigmate obliquo pyramido-conico; capsulis 7–8 mm. longis 3.5 mm. latis lanceo-ovoideis stramineis longitudinaliter trilobatis rostratis, placentis 2-ovulatis, seminibus 2–2.2 mm. longis 1.8–2 mm. diametro obovatis lucidis fusco-maculatis ad apicem truncatis.

DESCRIPTION OF TYPE: Shrub; at least 8 dm. tall; older branches 3–4 mm. in diameter, the bark brown, roughened by longitudinal furrows and transverse checks, the stipules mostly inconspicuous; leaf scars 0.8–1.5 mm. wide, lunate-oval, pale, with 3 bundle scars; twigs leafy for 1.5–7 cm., bearing 5–13 leaves, these ascending at 45°, crowded; leafy twigs 1.5–2.5 mm. in diameter, glabrous, reddish to greenish, roughened by the persistent stipules; nodes 1–8 mm., commonly 3 mm. apart; stipules 2.5–3.1 mm. long, 1.3–1.5 mm. wide, narrowly oblique deltoid or oblong deltoid, glabrous on the back and margin (though a lacerate membranous margin may appear ciliate on occasion), the base thickened, pillow-like, the midrib heavy and prominent; petioles 1–6 mm. long, stout, blackish, later pale from corky distortions and cracks; blades 3.3–15 cm. long, firm, thick, subcoriaceous, prominently raised fine reticulate veined, elliptic to oblance-elliptic, mostly obtuse, the base abruptly cuneate, the margin low undulate-crenulate, the lateral veins 8–10 on a side, ascending arcuate, wavy and interconnected well back from the margin; flowers single, axillary; peduncles 1 mm. or less in length, bibracteolate at apex; pedicels 2–3 mm. long, glabrous; peduncular bracts 1.5 mm. long, ovate, acute, glabrous; sepals 3.2–3.7 mm. long, 1 mm. wide, narrowly oblong-lanceolate, membranous, transparent, whitish or slightly greenish tinged, 5- or more-nerved, glabrous except for the margin sparsely ciliolate, the apex flat, dark brown; corolla irregular, the lower two thirds of each petal forming a claw, imbricate laterally, the upper ones outside, the lower inside, imitating a corolla tube, the limb expanding and reflexing in anthesis; lower petal the largest and much more fleshy, when boiled 6.2 mm. long, the claw 4.5 mm. long, 1.5 mm. wide, elliptic-ligulate, 3-nerved, membranous below the middle, above the middle gradually becoming thicker, fleshy and opaque, the limb 2.1 mm. long, 1.3 mm. broad, ciliolate, obovate, fleshy and opaque, the apex subacute, the limb and upper half of the claw rigidly channeled; lateral petals 6.3 mm. long, slight-

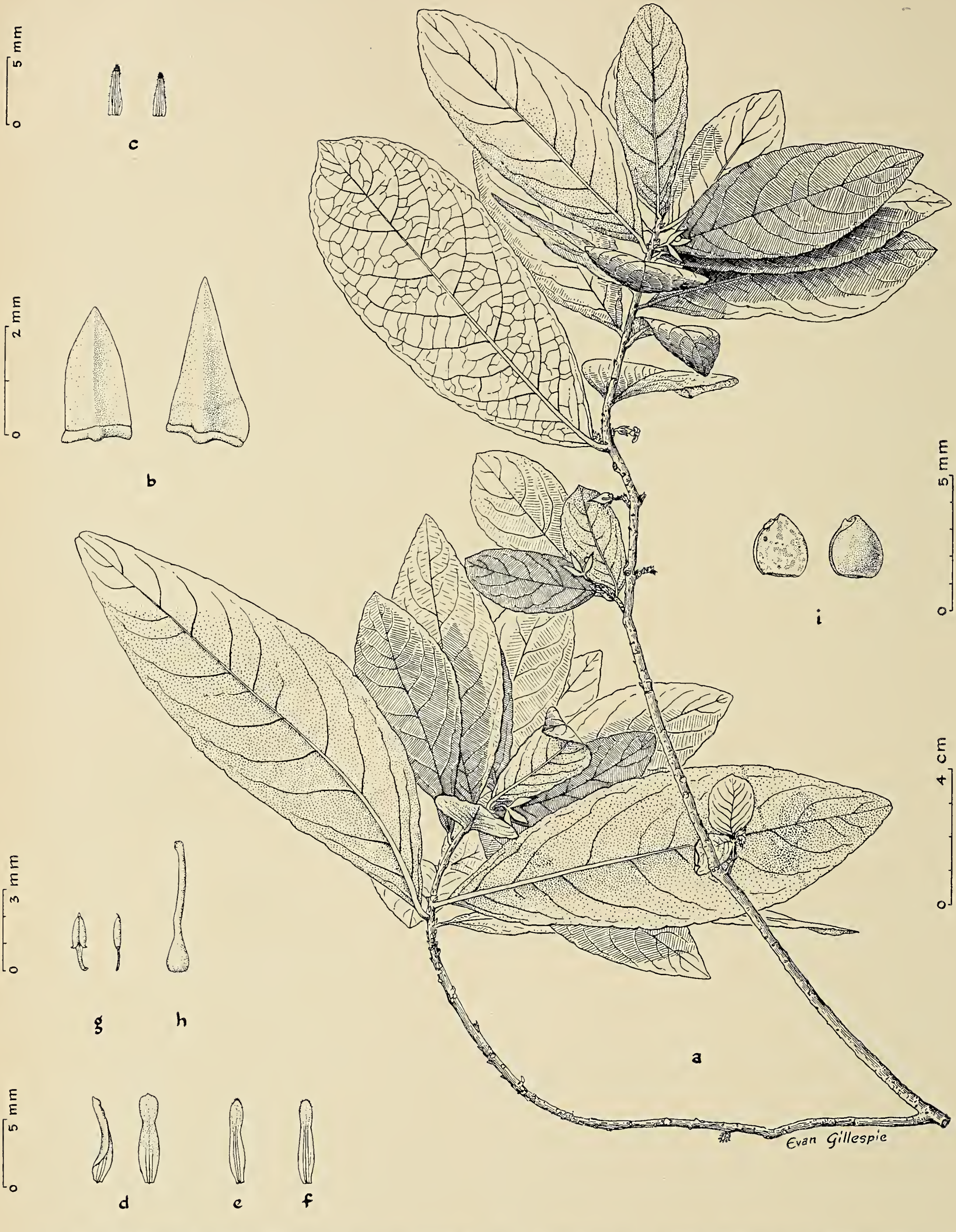


FIG. 1. *Isodendrion Forbesii. a*, Habit×½; *b*, stipules×8; *c*, sepals×2; *d*, lower petal×2; *e*, lateral petal×2; *f*, upper petal×2; *g*, lower stamen×4; *h*, pistil×4; *i*, seeds×4. From type specimen, Kipu Kai, Forbes 727.K.

ly contracted two thirds way from the base, claw 3.9 mm. long, 1.2 mm. wide, elliptic-ligulate, membranous, 3-nerved, the limb narrowly elliptic, ciliolate, fleshy thickened but the 3 veins visible; upper petals 6.2 mm. long, slightly contracted, the claw 4.2 mm. long, elliptic-ligulate, membranous, 3-nerved, the limb 2 mm. long, 0.9 mm. wide, narrowly oblong-elliptic, ciliolate; stamens slightly unequal, the lower ones 2 mm. long, the filaments 0.8 mm. long, ligulate, the anthers 1.2 mm. long, 0.5 mm. wide, narrowly elliptic, the base subsagittate, the connective with an apical flat mucro; ovary 1.2 mm. long, ovoid, longitudinally 3-lobed; style 3.6 mm. long, subulate; stigma lateral, pyramidal-conic; capsules 7–8 mm. long, 3.5 mm. wide, lance-ovoid, beaked by the persistent style, stramineous, deeply 3-lobed longitudinally; placentae 2-ovuled; seed 2–2.2 mm. long, 1.8–2 mm. in diameter, obovate, brown maculate, shining, the broad apex truncate and depressed.

TYPUS: Kauai, Haupu Range, left hand (east) side of Kipu Kai gap, on a ridge side of wet gully, only one plant seen, Nov. 1, 1916, *C. N. Forbes 727.K* (BISH), (st. lf. fl. fr.).

The specific name is given in honor of the collector, a vigorous explorer and botanist, Charles Noyes Forbes (1883–1920).

2. ***Isodendrion hawaiiense*** sp. nov.

ILLUSTRATIONS: Figure 2.

VERNACULAR NAME: "Wahine-noho-kula."

DIAGNOSIS TYPI: Frutex 1–2 m. alta, ramis 1.5–3.5 mm. diametro cortice griseo sublevi longituditer sulcato, cicatricibus 0.7–1.3 mm. latis depressi-rotundati-scutelliformibus prominentibus pallidis, fasciculis 3, ramulis foliferis 3–15 mm. longis 0.5–1 mm. diametro atrorubescentibus glabris a stipulis persistentibus abditis cum 6–9 foliis subcongregatis divergentibus, nodis 2–10 mm. plerumque 3 mm. distantibus, stipulis 2.8–3.3 mm. longis late ovato-deltoideis carina elevata et adpressi-puberulenta lateribus bruneis membranaceis marginibus ciliolatis, petiolis 5–10 mm. longis 0.3 mm. diametro gracilibus albo-puberulentis, laminis 2–5.7 cm. longis 10–28 mm. latis anguste ovato-ellipticis vel lanceolatis vel etiam anguste lanceolatis chartaceis sparse adpressi-puberulentis summe in venis apice obtuso vel breve mucronato venis secundariis 6–8 in uno latere valde adscendentibus apicibus diffusis, supra atri-viridibus infra pallidioribus marginibus obscure depressi-serrulatis, floribus solitariis axillaribus, pedunculis 2–3 mm. longis adpressi-puberulentis bibracteolatis in apice, pedicellis 2 mm. longis adpressi-puberulentis, sepalis subaequalibus 4 mm. longis carina 5-nervosa incrassata valde adpresse puberulenta lateribus membranaceis viridibus vel brunneis glabris marginibus ciliolatis, corollis irregularibus, laminis in tempo florescento reflexis, petala inferiore maxima 12.8 mm. longa (postquam bullanda), ungue subligulo 3-nervato marginibus membranaceis in medio incrassato opaquo canaliculato, limbo anguste elliptico 5.2 mm. longo 2 mm. lato subtile petaloideo praeter in basi incrassato, petalis lateralibus 10.9 mm. longis unguibus 6.9 mm. longis 1.8 mm. latis oblongo-ellipticis 3-nervatis marginibus membranaceis in medio carnoso canaliculato, limbo 4 mm. longo 1.7 mm. lato anguste elliptico carnoso exteriore piloso non pellucido marginibus sinuatis, petalis superioribus 11.1 mm. longis unguibus 1.5 mm. latis 3-nervatis marginibus latis membranaceis in medio ad apicem incrassato non pellucido, limbo 4.7 mm. longo 1.7 mm. lato anguste elliptico firmo carnoso non pellucido, staminibus aequalibus 2.8 mm. longis, filamentis ligulatis late nervosis ad mediam partem exteriorem glanduliferis ad apicem cruciformibus, apice connectivi aculeifero, antheris 1.5 mm. longis ovatis saccis anguste elliptici-oblongis, ovario 2 mm. longo ovoideo minime 3-lobato, stylo 5 mm. longo tereto sinuoso, stigmate obliquo, capsulis 12 mm. longis ovoideis glabris pallide viridibus valde nervosis a stylo rostratis, seminibus 3.2 mm. longis 1.8–2.2 mm. diametro obovatis olivaceo-fuscis ad apicem truncatis excavatis.

DESCRIPTION OF TYPE: Shrub; 1–2 m. tall, older branches 1.5–3.5 mm. in diameter; bark of older branches with long persistent stipules, but later rather smooth, gray, checked with longitudinal and a few lateral fissures; leaf scars 0.7–1.3 mm. wide, depressed rounded shield-shaped, prominent, pale, with 3 bundle scars; twigs leafy for 3–15 mm., bearing 6–9 leaves, rather crowded, diverging; upper leafy stem 0.5–1 mm. in diameter, dark reddish, glabrous, almost completely covered by the closely imbricate stipules; nodes 2–10 mm., commonly 3 mm. apart; stipules 2.8–3.3 mm. long, broadly ovate-deltoid, with the slender midrib thickened and raised and appressed puberulous, the wide sides brown membranous, the margins ciliolate; petioles 5–10 mm. long, 0.3 mm. in diameter, slender and white puberulent; blades 2–6.4 cm. long, 10–29 mm. wide, narrowly ovate-elliptic to lanceolate or even narrowly lanceolate, chartaceous, sparsely appressed puberulent, especially on the veins, secondary veins 6–8 on a side, sharply ascending, diffusing to the margin and interconnections, the apex obtuse or short mucronate, above dark green, below paler, the margin obscurely low serrulate; flowers single, axillary; peduncle 2–5 mm. long, appressed puberulent, bibracteolate at summit; pedicels 2–4 mm. long, appressed puberulent; sepals subequal, 4–5 mm. long, the thickened wide central strip densely appressed puberulent, appearing like one big midrib but containing 5 buried veins, the narrow sides thin, greenish or brownish, glabrous except for the ciliolate margins; corolla greenish, irregular, the lower two thirds of the petals forming a channel-like claw, the limb expanding and reflexing in anthesis; lower petal the largest, 12.8 mm. long (when boiled), contracted two thirds way from the base; claw almost ligulate but tapering slightly at base, 3-nerved from the base, the margins membranous, but the central strip thickened, fleshy, opaque, channeled, limb narrowly elliptic, 5.2 mm. long, 2 mm. wide, thickish at the very base, but beyond that thin petaloid and translucent; lateral petals 10.9 mm. long, strongly contracted two thirds way from the base, the claw oblong elliptic, 6.9 mm. long, 1.8 mm. wide, 3-nerved from the base, the margins membranous, the central strip opaque, thick, fleshy, firmly channeled, the limb 4 mm. long, 1.7 mm. wide, narrowly elliptic, pilosulous without, thick, fleshy, opaque, the margin wavy; upper petals 11.1 mm. long, contracted 3/5 way from the base, the claw 1.5 mm. wide, oblong-elliptic, 3-nerved, the wide margins membranous, the central strip gradually thickening upwards to the throat which is fleshy, opaque and strongly channeled, the limb 4.7 mm. long, 1.7 mm. wide, narrowly elliptic, firm, fleshy, opaque; stamens equal, 2.8 mm. long; filament ligulate with a broad nerve, at the middle this has a deltoid enlargement which supports a distal surface swelling bearing minute short glandular hairs, hence a nectary, apex of filament and base of connective joining in a cruciform enlargement as broad as the anther; connective narrowing upwards, and on the lower stamens bearing a prominent hamate prickle; anthers 1.5 mm. long, ovate in outline, the anther sacs narrowly elliptic-oblong, salient pointed at the base; ovary 2 mm. long, ovoid, lightly 3-ribbed; style 5 mm. long, sinuous, terete, stigma oblique; capsule 12 mm. long, ovoid, deeply 3-furrowed, glabrous, greenish, strongly veined, beaked by the persistent style; seeds 3.2 mm. long, 1.8–2.2 mm. in diameter, obovoid, olive brown, the apex truncate, sunken.

TYPUS: Iles Sandwich, Hawaii, 1851–1855, *J. Remy 535* (GH), (st. lf. fl.). An isotype (Paris) bears more data on an original ticket: "Violacée. (Vahinenohokula), Janvier, Bords du chemin dans le Kekaha, sur le lave decomposé au pied du Hualalai, Hawaii, attenu de 3 à 6 pied, fl. verdâtre."

J. Rémy (the correct spelling of his name, though on his printed labels the "e" was not accented) was in Hawaii for 5 years, long enough to learn to speak and write Hawaiian.

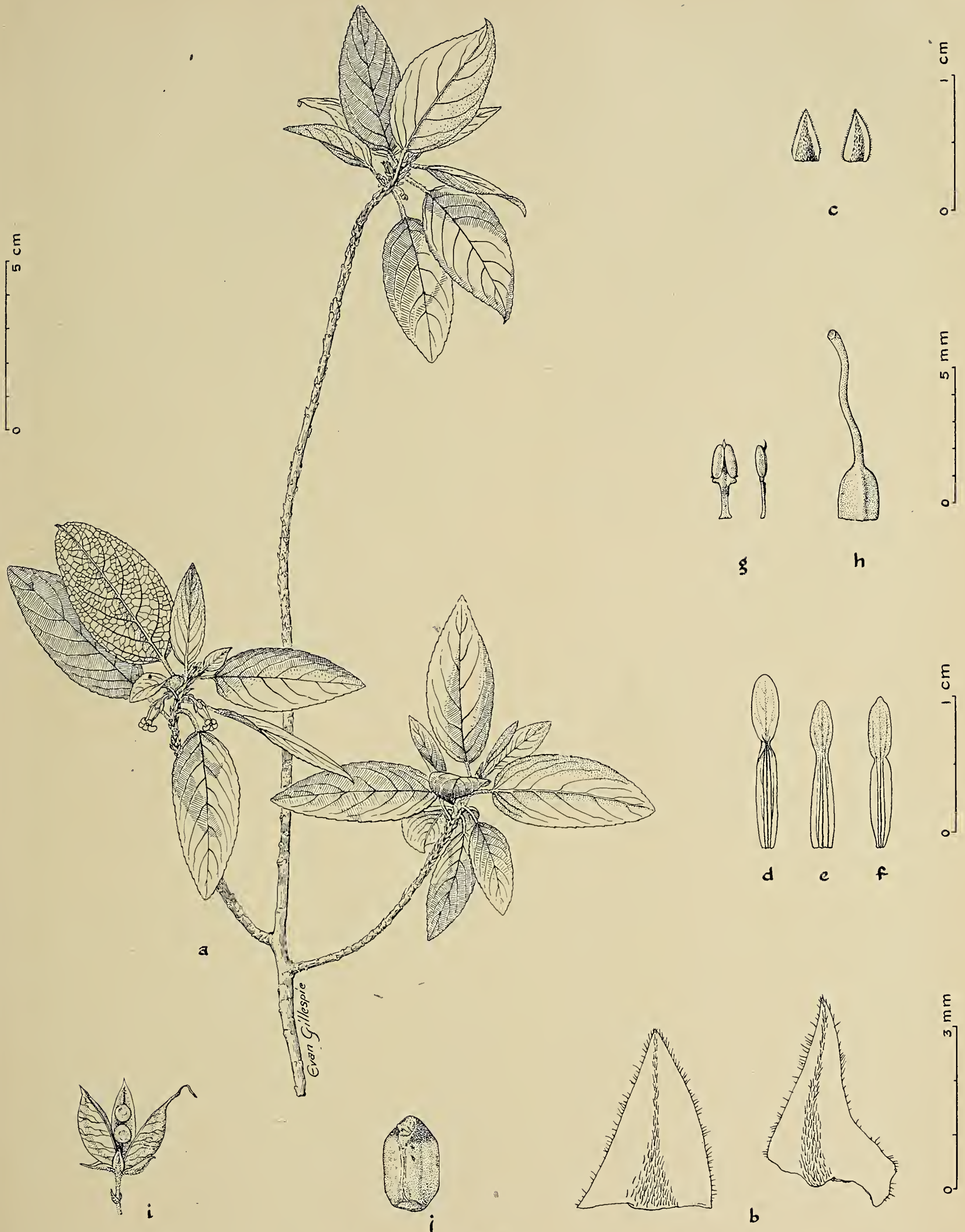


FIG. 2. *Isodendrion hawaiiense*. *a*, Habit×½; *b*, stipules ×8; *c*, sepals×2; *d*, lower petal×2; *e*, lateral petal×2; *f*, upper petal×2; *g*, lower stamen×4; *h*, pistil×4; *i*, capsule×1; *j*, seed×4. From the type, Hawaii, Remy 535, except *i* and *j* from isotype (P).

Hence, he certainly obtained the vernacular plant name from the natives and applied it correctly. It means the woman dwelling in the foothills. He recorded it in a French orthography, but it is here altered, "vahine" to "wahine," to make it conform to the established orthography of the Hawaiian language. The Hawaiian word "kekaha" means land unsuited for taro growth. As most of the land at the foot of Hualalai is of lava little decomposed and very arid this reference to it as rocky, waste land is apt. That makes the habitat more precise, but the locality is still vague.

The species is named for its occurrence on the island of Hawaii.

3. *Isodendrion Hillebrandii* sp. nov.

ILLUSTRATIONS: Figure 3.

DIAGNOSIS TYPI: Frutex, ramis glabris 1–4 mm. diametro a stipulis persistentibus asperatis deinde semilevibus griseis sulcatis, cicatricibus 0.7–1.5 mm. latis depresse scutelliformibus, fasciculis 3, ramulis foliferis 1–5 cm. longis cum 5–11 foliis divergentibus non condensatis 1–1.5 mm. diametro viridi- vel rubro-tinctis, nodis 1–6 mm. plerumque 2 mm. distantibus, stipulis 3–3.5 mm. longis late deltoideis carina incrassata et dense adpressi-puberulenta lateribus membranaceis brunneis marginibus ciliolatis, petiolis 5–7 mm. longis 0.4–0.5 mm. diametro gracilibus dense subadpressi-puberulentis, laminis 1.9–3.3 cm. longis 8–16 mm. latis ellipticis subcoriaceis supra atri-viridibus infra viridibus ab initio in venis adpressi-puberulentis praesertim infra sed supra deinde subglabris excepta ad basim, nervis secundariis 4–6 in uno latere valde adscendentibus arcuatis confluentibus, marginibus valde crenatis apicis obtusis, floribus solitariis axillaribus, pedunculis 2–4 mm. longis dense albis adpressi-puberulentis ad apicem bibracteolatis, bracteis 2 mm. longis sepalis simulantibus lanceo-ovatis ciliatis in dorso puberulentis, pedicellis 1.5–3 mm. longis dense albis adpressi-puberulentis, sepalis 3.6–3.8 mm. longis 1.8 mm. latis oblongo-ovalibus 3–6-nervosis carina incrassata valde adpressi-puberulenta lateribus membranaceis glabris marginibus ciliolatis, petalis irregularibus exterioribus adpressi-puberulentis petala inferiore 11.9 mm. longa (postquam bullanda), ungue 7.4 mm. longo 2.2 mm. lato anguste elliptico 5-nervato in medio incrassato ad apicem incrassato et canaliculato non pellucido, limbo 4.5 mm. longo 2.5 mm. lato carnoso firmo marginibus sinuatis, petalis lateralibus 10.7 mm. longis, ungue 6.7 mm. longo oblique oblanceo-oblongo asymmetrico in medio incrassato, limbo 4 mm. longo 1.9 mm. lato oblique oblongo-ovali nervoso incrassato non pellucido, petalis superioribus 10.8 mm. longis subligulatis, ungue 7 mm. longo 1.9 mm. lato angustissime elliptico 3-nervato in medio nervoso et ad apicem semi-incrassato marginibus membranaceis, limbo 3.8 mm. longo 1.9 mm. lato oblique oblongo-ovali incrassato et nervoso, staminibus 1.5–1.8 mm. longis subaequalibus omnibus in apicibus connectivorum armatis mucro 0.1 mm. longo, filamentis 0.5–0.7 mm. longis subulatis ad basem exteriore inflato glanduloso, antheris 1.3 mm. longis 0.8 mm. latis oblongis saccis in basi submucronatis, ovario 2.8 mm. longo 1.2 mm. diametro lanceoloideo, stylo 5.1 mm. longo crasse filiforme, stigmate oblique suborbiculare, fructu ignoto.

DESCRIPTION OF TYPE: Shrub; stems glabrous, older ones 1–4 mm. in diameter, roughened by the long persisting stipules, later nearly smooth, gray, checked with longitudinal and transverse fissures; leaf scars 0.7–1.5 mm. wide and half as high, very depressed rounded shield-shaped, with 3 bundle scars; twigs leafy for 1–5 cm., bearing 5–11 leaves that are well spaced and divergent; upper leafy stem 1–1.5 mm. in diameter, greenish or reddish; nodes 1–6 mm., commonly 2 mm. apart; stipules 3–3.5 mm. long, broadly deltoid, the midrib heavy, raised and densely appressed puberulent, the sides membranous, brown, the margin ciliolate; petioles 5–7 mm. long, 0.4–0.5 mm. in diameter,

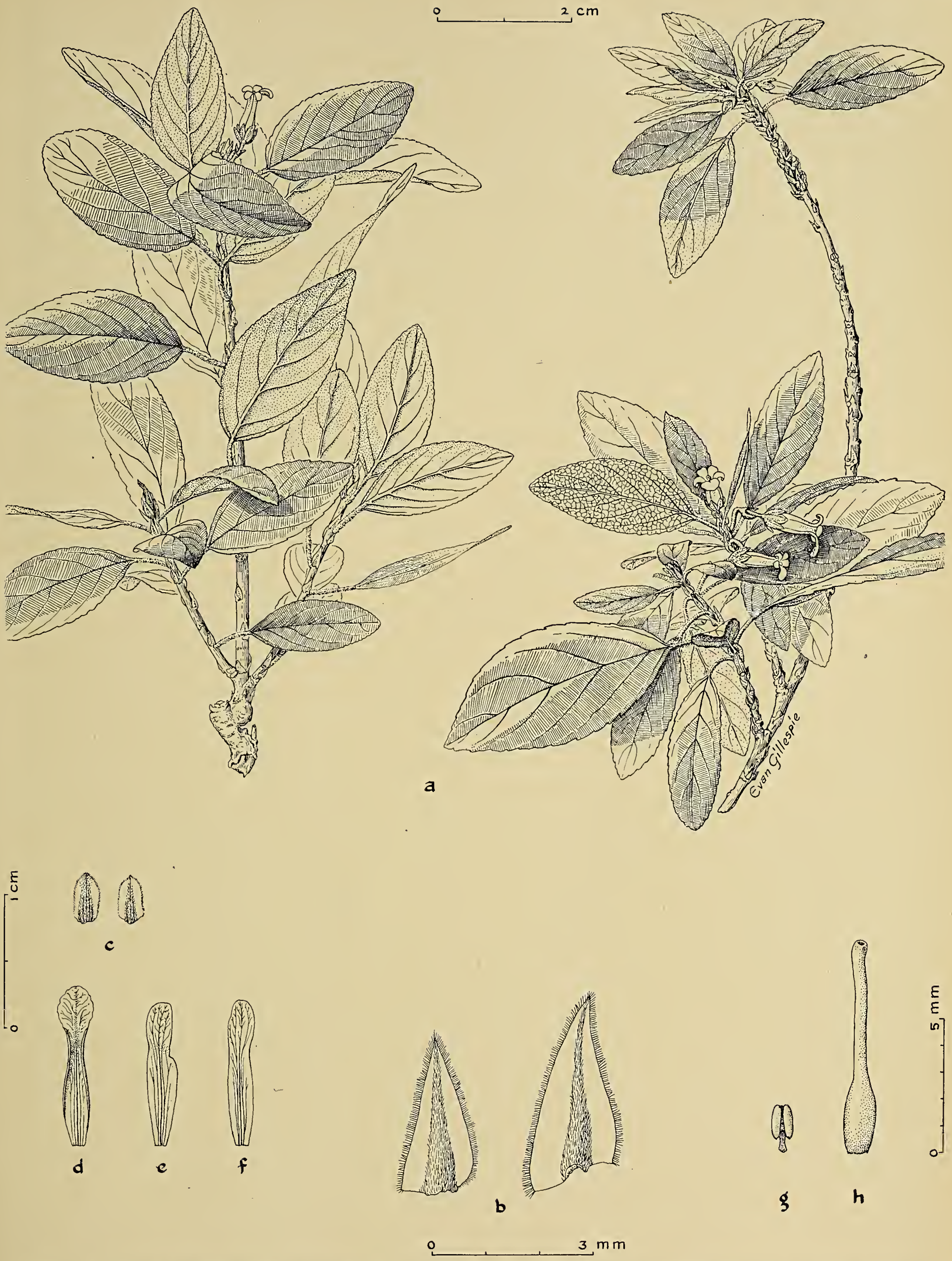


FIG. 3. *Isodendrion Hillebrandii*. *a*, Habit×1; *b*, stipules×8; *c*, sepals×2; *d*, lower petal×2; *e*, lateral petal×2; *f*, upper petal×2; *g*, stamen×4; *h*, pistil×4. From the type, Waianae, Hillebrand.

slender, densely subappressed puberulent; blades 1.9–3.3 cm. long, 8–16 mm. wide, elliptic, subcoriaceous, above dark green, below green, at first appressed puberulent on the veins above and below but more densely so below, above finally subglabrate except on the main veins towards the base, the margin strongly crenate, the apex obtuse, secondary veins 4–6 on a side, sharply ascending, inarched and connecting well back from the margin; flowers single, axillary; peduncles 2–4 mm. long, densely appressed white puberulent, bibracteolate at apex; bracts 2 mm. long, sepaloid, lance-ovate, ciliate, puberulent on the back; pedicels 1.5–3 mm. long, densely appressed white puberulent; flowers axillary, single, the peduncles 2–4 mm. long, appressed white puberulent, bibracteolate at apex; pedicels 2–3 mm. long, appressed white puberulent; sepals 3.6–3.8 mm. long, 1.8 mm. wide, oblong-oval, the thickened central strip 3–6-nerved from the base, this strip and a little of the adjacent membranous sides toward the tip closely appressed puberulent, the margin ciliolate; corolla irregular, appressed puberulent distally, the lower two thirds of the petals forming a channel-like claw, imbricate laterally, the upper ones outside, the lower inside, imitating a corolla tube, the limb expanding and reflexing in anthesis; lower petal the largest, 11.9 mm. long (when boiled), the claw 7.4 mm. long, 2.2 mm. wide, narrowly elliptical channeled, 5-nerved from the base, but the lateral nerves forking, the central strip of firm tissue containing the veins, the broad margins membranous for the lower two thirds, then in the upper third the entire width veiny, much thickened, fleshy, firmly channeled, opaque, the slightly contracted neck long, the limb 4.5 mm. long, 2.5 mm. wide, ovate, thick, fleshy, firm, with several veins and the margin crimped up between the vein ends; lateral petals 10.7 mm. long with a short distinct neck, the claw 6.7 mm. long, obliquely oblance-oblong, the upper side larger and more abruptly narrowed at apex, the central strip thickened and opaque in the upper third, the limb 4 mm. long, 1.9 mm. wide, obliquely oblong-oval, veiny, thickened and opaque; upper petals 10.8 mm. long, almost ligulate though there is a very shallow neck one third way from the apex, the claw 7 mm. long, 1.9 mm. wide, very narrowly elliptic, 3-nerved from the base, but the lateral nerves soon forking, the central strip veiny and slightly thickened especially towards the apex, the wide margins membranous, the whole slightly channeled; the limb 3.8 mm. long, 1.9 mm. wide, obliquely oblong-oval, veiny, thickened and opaque; stamens subequal, all with a blunt, recurved mucro 0.1 mm. long at the apex of the connective, 1.5–1.8 mm. long, the filaments 0.5–0.7 mm. long, subulate; the connective swollen and probably glandular on the distal side just above the base; anthers 1.3 mm. long, 0.8 mm. wide oblong, the anther sacs submucronate at base; ovary 2.8 mm. long, 1.2 mm. in diameter, lanceoloid; style 5.1 mm. long, stout filiform; stigma subterminal, distal, suborbicular; fruit unknown.

TYPUS: Oahu, Waianae, on bare rocky hills, in 18—. *W. Hillebrand* (GH), (st. lf. fl.).

Hillebrand in his flora (p. 18) includes this in *I. pyrifolium* Gray and cites this collection as "in Waianae," apparently meaning Waianae Valley rather than on the Waianae Mountains. Furthermore, Rock saw the duplicate of this in 1914 in Berlin, and copied the data as "1869. On rocks in the plains of Waianae, Oahu."

The species is named in honor of Dr. William Hillebrand (1821–1886), physician and botanist, resident in Honolulu from 1850 to 1871.

4. *Isodendrion Hosakae* sp. nov.

ILLUSTRATIONS: Figure 4.

DIAGNOSIS TYPI: Frutex 45–75 cm. alta, ramis 4–8 mm. diametro cortice griseo deinde albescenti asperato cum sulcis longitudinis et stipulis persistentibus, cicatricibus 1.2–1.5 mm. latis lunati-ellipticis pallidis suberatis,

fasciculis 1 grandis transversis, ramulis foliferis 1–18 cm. longis cum 7–29 foliis divergentibus deinde reflexis subcondensatis, ramulis 1–2.3 mm. diametro subviridibus et albo-adpressi-puberulentis plerumque a stipulis rigidis imbricatis clausis, nodis 1–6 mm. plerumque 1.5 mm. distantibus, stipulis 2.5–4 mm. longis late oblique ovatis cordatis in parte medio dense adpressi-albi-puberulentis carina incrassata lateribus membranaceis brunneis glabris marginibus albi-ciliatis, petiolis 3–11 mm. longis albi-puberulentis, laminis 2–6 cm. longis 6–17 mm. latis coriaceis lanceolatis supra nigri-viridibus sublucidis in nervo mediale et minus in nerviis secundariis albi-puberulentis infra luteo-viridibus et eodem modo puberulentis valde reticulato-nervosis margine subcrenulatis, nerviis secundariis 5–7 in uno latere valde adscendentibus confluentibus, floribus odoratis singulis axillaribus, pedunculis 2–4 mm. longis albi-adpressi-puberulentis, pedicellis 2–2.5 mm. longis albi-adpressi-puberulentis, bracteis peduncularibus 2.3–3.2 mm. longis in medio puberulentis marginibus ciliatis, sepalis 4.5–5.5 mm. longis 2.3–2.7 mm. latis lanceo-ovatis apiculatis firmis viridibus in carina incrassata 5-nervosa et dense adpressi-puberulentis lateribus angustis membranaceis glabris marginibus ciliatis, corollis albescentibus irregularibus, petalis extra in linea media et limbo toti dense adpressi-puberulentis, petala inferiore (in vivo) 18 mm. longa (in sicco 12–14 mm. longa), ungue 10 mm. longo 3-nervoso ligulato canaliculato ad apicem incrassato et carnoso, limbo 7 mm. longo 4.5 mm. lato ovali crassi carnoso non pellucido in linea media sulcato, petalis lateralibus 15.5 mm. longis unguibus 9.7 mm. longis elliptici-ligulatis 3-nervosis ad apicem incrassatis et canaliculatis, limbis 6 mm. longis ovalibus subacutis carnosis praesertim ad basim, petalis superioribus 14.5 mm. longis unguibus elliptici-ligulatis 3-nervosis marginibus membranaceis in linea media incrassatis, limbis 5.5 mm. longis ovalibus praesertim ad basim non pellucidis et carnosis, staminibus subaequalibus 3.5 mm. longis, filamentis 1.3 mm. longis validis subulatis, antheris 1.3 mm. longis ovatis connectivo staminarum inferiorum in aculea valida adscendenta prolongato, ovario 2 mm. longo 3-anguloso, stylo 6.5 mm. longo crasse filiforme, stigmate obliquo crateriforme, capsulis 9–10 mm. longis 6–8 mm. diametro ellipsoideis profunde 3-lobatis viridibus et rubro-tinctis valde nervosis rostratis, placentis 2- vel 4-ovulatis, seminibus 2.8–3 mm. longis 1.8–2 mm. diametro obovoideis lucidis olivaceis et atri-maculatis ad apicem truncatis minime rotundato-excavatis.

DESCRIPTION OF ALL SPECIMENS EXAMINED: Shrub; 45–75 cm. tall; older branches 4–8 mm. in diameter, with the bark gray, roughened by longitudinal furrows, and also by the long persisting stipules, finally the bark whitish; leaf scars 1.2–1.5 mm. wide, lunate-elliptic, pale, corky; bundle scar 1, large, transverse; twigs leafy for 1–18 cm., bearing 7–29 leaves, these spreading and eventually reflexing, rather crowded; upper leafy stems 1–2.3 mm. in diameter, greenish, the surface white appressed puberulent but largely concealed by the persistent, rigid, imbricate stipules; nodes 1–6, commonly 1.5 mm. apart; stipules 2.5–4 mm. long, broadly oblique ovate, the base cordate, the midrib heavy, raised, it and the central strip densely white appressed puberulent, the wide sides membranous, brown, glabrous, the margins white ciliate; petioles 3–11 mm. long, white puberulent; blades 2.6 cm. long, 6–19 mm. wide, coriaceous, lanceolate, the margin perceptibly remotely low crenulate, above dark green, sublucid, white puberulent on the midrib and remotely so on the smaller veins, below yellowish green and similarly puberulent, strongly reticulate veined; the secondary veins 5–7 on a side, sharply ascending and inarched connecting well in from the margin; flowers fragrant, single, axillary; peduncle 2–8 mm. long, appressed white puberulent; pedicels 2–4 mm. long, appressed white puberulent; peduncular bracts 2.3–3.2 mm. long, puberulent on midrib and margin like the stipules; sepals

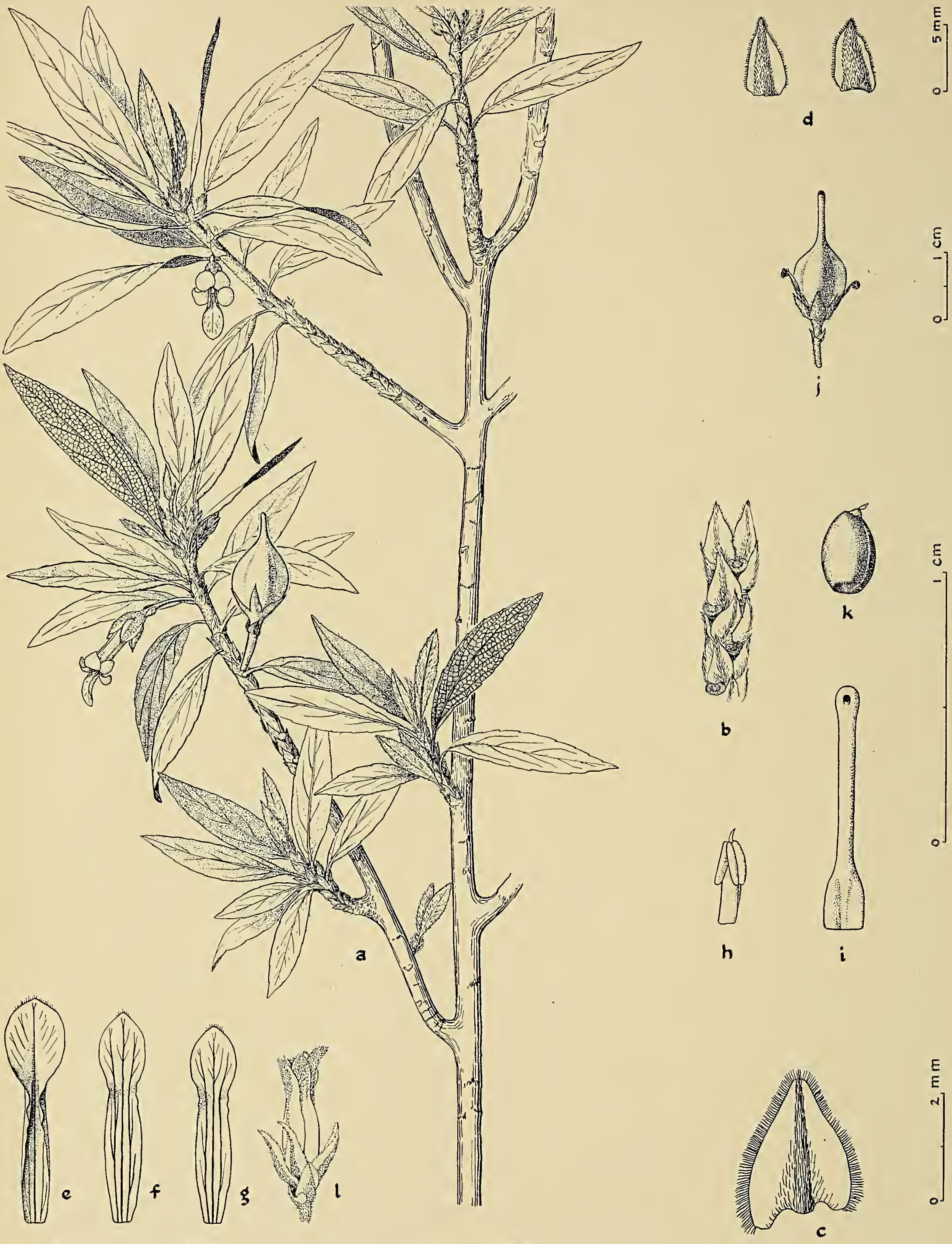


FIG. 4. *Isodendrion Hosakae*. *a*, Habit×1; *b*, stem and stipules×4; *c*, stipule×8; *d*, sepals×2; *e*, lower petal×2; *f*, lateral petal×2; *g*, upper petal×2; *h*, stamen×4; *i*, pistil×4; *j*, capsule×1; *k*, seed×4; *l*, bud×4. From the type, Waikaloa, Hosaka 3,594.

4.5–5.5 mm. long, 2.3–2.7 mm. wide, lance-ovate, apiculate, firm, greenish, 5-nerved in the thickened central strip and there closely appressed puberulent, the narrow sides membranous, glabrous, the margins ciliate; corolla whitish, irregular, the lower two thirds of each petal forming a channel-like claw, imbricate laterally, the upper ones outside, the lower inside, imitating a corolla tube, the petals without densely appressed puberulent up the middle of the claw and generally on the limb, the limb expanding and reflexing in anthesis; lower petal the largest, 18 mm. long when fresh (12–14 when dried), the claw 10 mm. long, 3-nerved from the base, ligulate, channeled and towards the apex thickened and very fleshy, the limb 7 mm. long, 4.5 mm. wide, oval, thick, fleshy, opaque, creased down the middle; lateral petals 15.5 mm. long, the claw 9.7 mm. long, elliptic-ligulate, 3-nerved from the base, thickened and channeled towards the apex, the limb 6 mm. long, oval, subacute, fleshy especially at base; upper petals 14.5 mm. long, the claw elliptic-ligulate, 3-nerved from the base, the margins membranous, the center strip thickened, the limb 5.5 mm. long, oval, opaque and fleshy particularly at base; stamens subequal 3.5 mm. long, the filament 1.3 mm. long, stout subulate; anthers 1.3 mm. long, ovate, the connective of the lower stamens prolonged into a stout ascending prickle; ovary 2 mm. long, ovoid, 3-angled; style 6.5 mm. long, stout filiform; stigma oblique, crateriform; capsule 7–10 mm. long, 6–8 mm. in diameter, ellipsoid in outline, deeply 3-lobed, green and tinged with dull red, prominently veined, beaked with the persistent style; placentae 2- or 4-ovulate; seeds 2.8–3 mm. long, 1.8–2 mm. in diameter, obovoid, the surface shining, olivaceous with blackish mottlings, the apex truncate, small circular excavate.

TYPUS: Island of Hawaii, South Kohala, Waikaloa, el. 3,390 ft., rare, near top of a cinder cone, small woody shrub 1½ to 2½ ft. high, fl. whitish, fragrant, associated with *Dodonaea*, *Wikstroemia*, *Railliardia Menziesii*, *Bidens filiformis*, *Sida*, and *Eragrostis*, Feb. 3, 1949, *E. Y. Hosaka 3,594* (BISH), (st. lf. fl. fr.).

SPECIMENS EXAMINED: Hawaii, Waikaloa, the same locality as above, Nov. 4, 1948, *E. Y. Hosaka 3,593* (BISH), (root, st. lf. b. fl. fr.).

The species is named for the collector, Edward Yataro Hosaka (1906–).

5. *Isodendrion lanaiense* sp. nov.

ILLUSTRATIONS: Figure 5.

DIAGNOSIS TYPI: Frutex, ramis erectis simplicibus 3–4 mm. diametro, cortice rufo-brunneo cum sulcis multis propinquis deinde griseo et subsuberoso, nodis prominentibus, internodis 1–10 mm. longis juventioris cum stipulis rigidis persistentibus, cicatricibus 1.3–1.8 mm. latis depresso-obcordatis, fasciculis 1 late lunatis, ramulis adpressi-puberulentis etiam in parte defoliata et asperatis a stipulis, ramulis foliosis 5–15 mm. longis puberulentis sed a stipulis imbricatis clausis, foliis 4–9 adscendentibus vel divergentibus plumam formantibus, stipulis 3.9–5 mm. longis 1.4–1.8 mm. latis oblique ovatis vel oblongo-lanceolatis carina incrassata pallida et adpressi-puberulenta lateribus brunneis glabris et marginibus ciliolatis, petiolis 3–5 mm. longis adpressi-puberulentis, laminis 13–40 cm. longis 8–19 mm. latis ovalibus chartaceis plus minusve perpetuiter in nervis puberulis apice breve apiculato vel obtuso marginibus apiculato-crenulatis, floribus axillaribus pluribus, pedunculis pedicellisque 2–4 mm. longis adpressi puberulentis, bracteis 3–4 mm. longis stipulaceis ovatis, sepalis 3–3.5 mm. longis ovatis in nervo centrali maximi albi-adpressi-puberulis lateribus membranaceis brunneis marginibus ciliolatis, petalis inaequalibus limbo extra in nervis adpressi-puberulentis, petala inferiore maxima spatulata 11 mm. longa (postquam bullanda), limbo 3 mm. longo 2.5 mm. lato ovali crassi carnoso in linea media sulcato apice retuso revoluto, ungue 7.5 mm. longo 1.5 mm. lato subrigido canaliculato 5-

nervoso marginibus membranaceis, petalis lateralibus 10 mm. longis anguste spatulatis limbis 2.8 mm. longis 1.5 mm. latis ovatis firmis valde pinnati-nervosis, unguibus 7 mm. longis 1.3 mm. latis canaliculatis in medio firmis 3-nervosis marginibus membranaceis, petalis superioribus angustiore spatulatis limbis 2 mm. longis 1.5 mm. latis ellipticis firmis, unguibus 7.2 mm. longis 1.3 mm. latis 3-nervosis firmis canaliculatis marginibus membranaceis, staminibus subaequalibus, filamentis 0.8–1 mm. longis 0.2 mm. latis in basi planis attenuatis, antheris 0.9 mm. longis 0.5 mm. latis sagittato-ovatis, connectivo armato in apice aculeam incurvatam 0.2 mm. longam ferrentibus, capsulis 8–11 mm. longis ovoideis profunde 3-lobatis apice rostrato, placentis 4-ovuliferis biseminiferis, seminibus 3–3.5 mm. longis 2–2.2 mm. diametro obovatis olivaceo-brunneis sublucidis in apice truncatis excavatis.

DESCRIPTION OF ALL SPECIMENS EXAMINED: Shrub; branches often erect and simple, the older branches 3–4 mm. in diameter, bark reddish brown with many close longitudinal fissures, finally somewhat corky and gray, the nodes prominent and salient; internodes 1–10 mm. long, the younger rigidly scaly from the persistent stipules; leaf scars 1.3–1.8 mm. wide, depressed obcordate; bundle scar 1, broad lunate; small twigs appressed puberulent and, even well below the leaves, rough from the stiff, persistent stipules; young branchlets leafy for a distance of only 5–15 mm., the bark appressed puberulent but this almost completely concealed by the overlapping stipules; the leaves 4–9, ascending or spreading in a close terminal plume; stipules 3.9–5 mm. long, 1.4–1.8 mm. wide, obliquely ovate or oblong-lanceolate, with a heavy, thickened, pale midrib and dark brown body, appressed puberulent on midrib and central strip, the membranous margin ciliolate; petioles 3–5 mm. long, appressed puberulous; blades 1.3–5.0 cm. long, 8–28 mm. wide, oval, chartaceous, more or less permanently appressed puberulous on the veins, apex short apiculate or obtuse, margins apiculate crenulate; flowers axillary, numerous; peduncles 2–4 mm. long; pedicels single, 5–8 mm. long, closely appressed puberulous, at the apex of the peduncle bearing two subopposite bracts like the stipules but ovate, 3–4 mm. long; sepals 3–4 mm. long, ovate, appressed white puberulous on the enormous midrib, the sides membranous, brown, the margins ciliolate; corolla irregular, the lower three fifths of the petals forming a concave channel-like claw, the limb expanding and reflexing in anthesis, the outer surface appressed puberulent along the veins; lower petal longer and larger than the others, spatulate, 11 mm. long (when boiled), the limb 3 mm. long, 2.5 mm. wide, oval, thick and fleshy, the halves down-curved to the narrow median crease, the apex retuse and revolute; claw 7.5 mm. long, 1.5 mm. wide, rather firm, concave and channeled, 5-nerved from the base, the margin membranous; lateral petals 10 mm. long, narrowly spatulate, the limb 2.8 mm. long, 1.5 mm. wide, ovate, firm, strongly pinnate nerved, the claw 7 mm. long, 1.3 mm. wide channeled, the body firm, the margins membranous, 3-nerved at base; upper petals 8.3 mm. long, very narrowly spatulate, the limb 2 mm. long, 1.5 mm. wide, elliptic, firm, the claw 7.2 mm. long, 1.3 mm. wide, the margins membranous, the rest firm, channeled, 3-nerved at base; stamens subequal, filaments 0.8–1 mm. long, 0.2 mm. wide at base, flat, tapering upwards; anthers 0.9 mm. long, 0.5 mm. wide, sagittate-ovate, the connective bearing from the distal side of its apex a firm, incurved prickle 0.2 mm. long; capsule 8–11 mm. long, ovoid, deeply 3-furrowed, the apex tapering into the persistent style, the placentae 4-ovuled, the attachment in two oblique pairs, 2-seeded; seeds 3–3.5 mm. long 2–2.2 mm. wide, obovate, the apex truncate, sunken, the surface olive brown, sublucid.

TYPUS: Lanai, collected by Dr. *William Hillebrand and J. M. Lydgate*, ex Herb. J. M. Lydgate (BISH), (st. lf. fl. fr.).

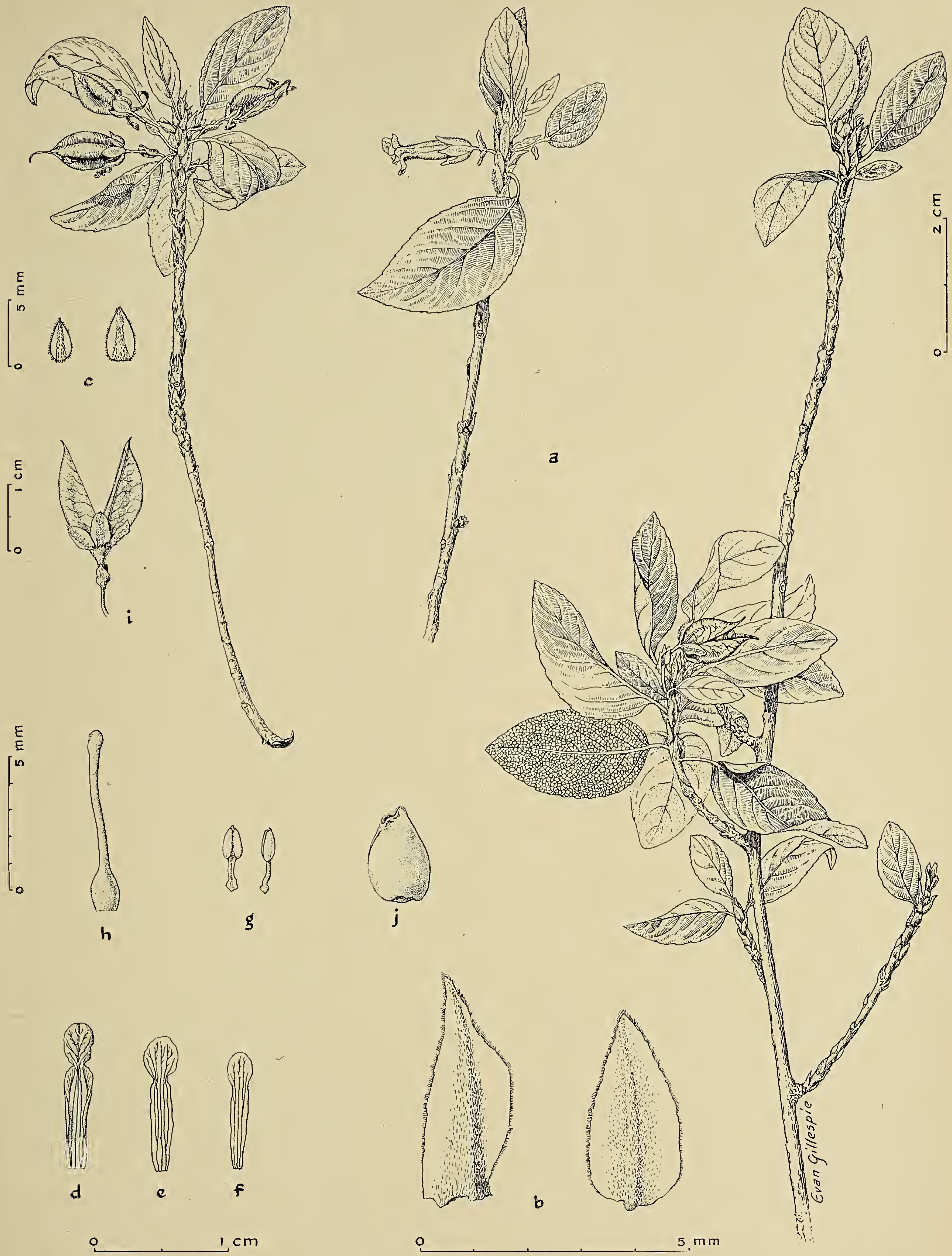


FIG. 5. *Isodendrion lanaiense*. *a*, Habit×1; *b*, stipules×8; *c*, sepals×2; *d*, lower petal×2; *e*, lateral petal×2; *f*, upper petal×2; *g*, stamen×4; *h*, pistil×4; *i*, capsule×1; *j*, seed×4. From the type, Lanai, Hillebrand 17,060.

SPECIMENS EXAMINED: Lanai, 18—, *W. Hillebrand* (GH), (s. lf. fl. fr.); Lanai, rec'd 12/'72, *W. Hillebrand* (K), (st. lf. b. fl. fr.); Lanai, July 1870, [*W. Hillebrand*], Ex Museo botanico Berolinensi, College of Hawaii Herbarium 17,060 [i. e., J. F. Rock added his number 17,060 which is not a Hillebrand number]. Two original tickets are in Hillebrand's writing, and the printed label, Ex Mus. bot. Berol., is characteristic of the set of isotypes or clastotypes of Hillebrand's species, obtained by Professor Rock from the Berlin Museum for the College of Hawaii and now deposited in the Bishop Museum. There is also a third sheet from Lanai with the Berlin label and a College of Hawaii label, Rock No. 17,060. It seems positive that these are all duplicates from the Hillebrand collection on Lanai, one given to his young field companion, Lydgate, and two later obtained by Rock from the Hillebrand collection after its placement in Berlin. The Berlin originals, two sheets seen by Rock in 1914, were probably destroyed in World War II. The specimen at Kew: Lanai, Hillebrand, is also doubtless an isotype.

The species is named for its occurrence on the island of Lanai.

6. **Isodendrion laurifolium** Gray, Amer. Acad. Arts and Sci., Proc. 2: 324, 1852; Gray, U. S. Explor. Exped. [official ed.] 15 (1): 96, 1854; [public ed.] Botany, Phanerogamia 1: 96, 1854.

ILLUSTRATIONS: Figure 6.

DESCRIPTION OF TYPE: Shrub; glabrous, erect, with a few short, ascending branchlets; older branches 3 mm. in diameter, the bark smooth, pale brown, with a few longitudinal fissures; leaf scars 2 mm. wide, suborbicular-shield-shaped, pale, with 3 bundle scars; twigs leafy for 16 cm., bearing 15 or more leaves, these ascending at about 45° divergence from the stem, not crowded; upper leafy stem 1.8–2.9 mm. in diameter, smooth, shading downwards from green to reddish brown, roughened by the rigid stipules; nodes 2–20, commonly 2–10 mm. apart; stipules 1.9–3 mm. long, obliquely linear-lanceolate, glabrous, the midrib prominent, raised, towards the base broadened, the narrow margins brown membranous, glabrous and smooth; petioles 1–2.5 mm. long, stout, becoming corky wrinkled; blades 2.2–9.2 cm. long, 11–30 mm. wide, firm, subcoriaceous, prominently finely reticulate veined, linear-oblanceolate, the base abruptly short cuneate, the apex subacute, the margin slightly undulate or even remotely low subserrate; flowers single, axillary; peduncles 2 mm. long, bracteate; pedicel 1 mm. long; sepals 1.9–2.25 mm. long, 0.9–1 mm. wide, deltoid to obliquely lance-deltoid, glabrous, chartaceous, nerved only by the slender midrib; corolla irregular, the lower two thirds of each petal forming a channel-like claw, imbricate laterally, the upper ones outside, the lower inside, imitating a corolla tube, the limb expanding and reflexing in anthesis; lower petal the broadest and equalling the upper ones in length, 7.1 mm. long (when boiled), claw 5.2 mm. long, 1.3 mm. wide, the lower two thirds membranous, 3-nerved from the base but the lateral nerves forking above, the distal quarter opaque, fleshy, strongly channeled, the limb 1.9 mm. long, 1.4 mm. wide, oval, thick and fleshy, the veins almost invisible; lateral petals 6.9 mm. long, somewhat ligulate, scarcely contracted two thirds from the base, claw almost plane, membranous, 3-nerved, ligulate but slightly widened near the distal end, the limb narrowly elliptic, the veins obscured in the fleshy opaque tissue; upper petals 7.1 mm. long, slightly contracted and channeled two thirds way from the base, the claw 5.3 mm. long, ligulate but broadened near the base, membranous, 3-nerved, the limb 1.8 mm. long, 0.8 mm. wide, narrowly elliptic, fleshy and opaque; stamens about equal, unarmed, 1.7–1.9 mm. long, the filaments 0.8–1 mm. long, subulate, the anthers 0.8–0.9 mm. long, 0.7 mm. wide, ovate above the sagittate base; ovary 3.4 mm. long, 2.2 mm. in diameter, ovoid, longitudin-

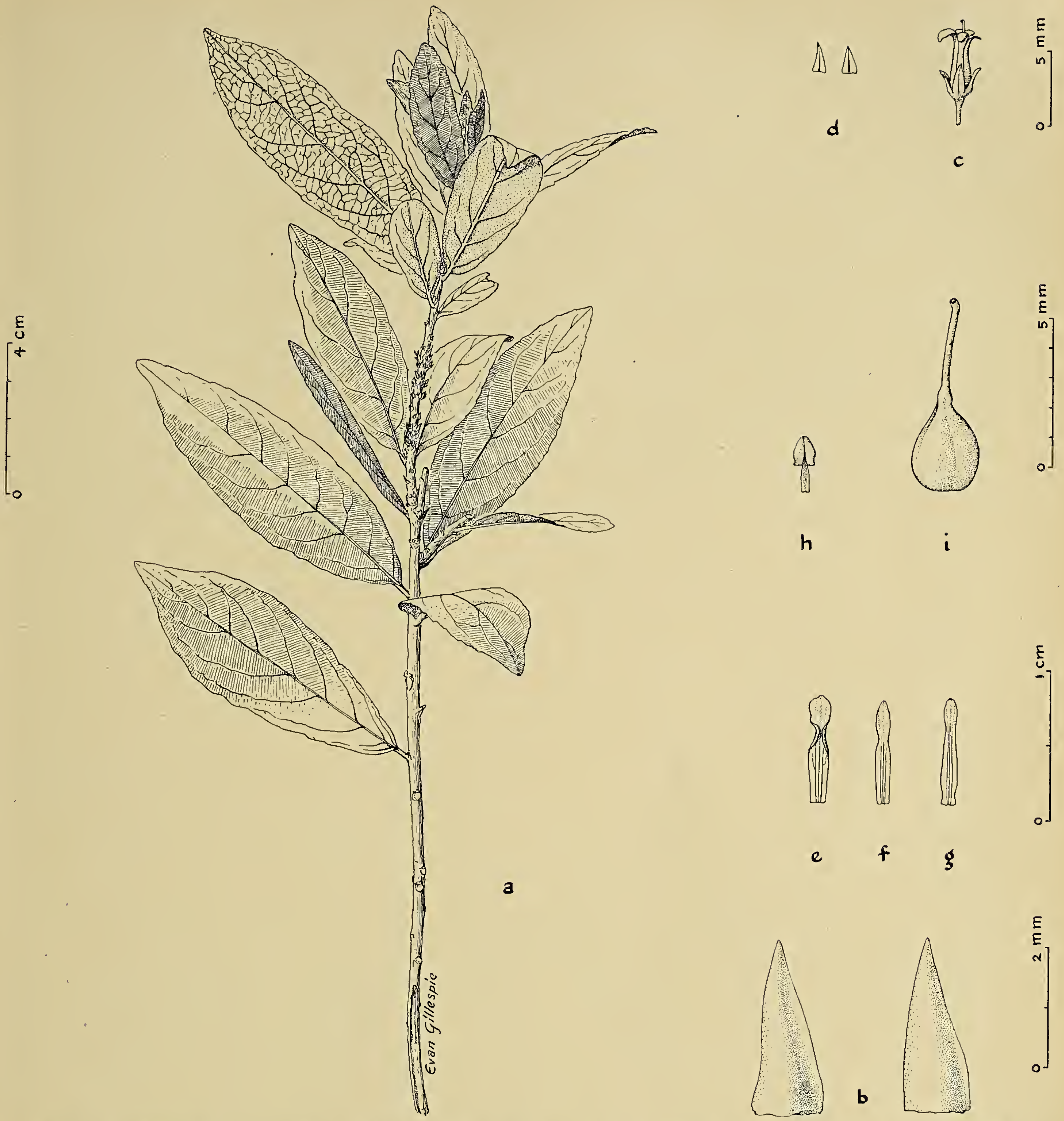


FIG. 6. *Isodendrion laurifolium*. *a*, Habit×½; *b*, stipules×8; *c*, flower×2; *d*, sepals×2; *e*, lower petal×2; *f*, lateral petal×2; *g*, upper petal×2; *h*, stamen×4; *i*, pistil×4. From type, Kaala Mts., Wilkes Exped.

ally 3-lobed; style 3 mm. long, slender cylindric; stigma subterminal, orbicular, penicillate; fruit not seen.

TYPE: Sandwich Islands, Oahu, Kaala Mts., U. S. Exploring Expedition under Capt. Wilkes (US), (st. lf. fl. i. fr.). Type examined. Also isotype (GH), (st. lf.).

In the original description Gray stated (1852: 96) that the blades were "oblong-lanceolate, somewhat narrowed at both ends, obtuse at the base . . ." "Only a single and incomplete specimen of this plant was gathered." The isotype in the Gray Herbarium is only a scrap, a branch tip with three expanded leaves. The type in the U. S. National Herbarium is herewith illustrated in detail. The blade shape is better described as oblanceolate.

The species was obviously named from *Laurus*, the laurel tree; and Latin *folium*, leaf, indicating a resemblance in the leaves to those of the laurel.

7. **Isodendrion longifolium** Gray, Amer. Acad. Arts and Sci., Proc. 2: 324, 1852; Gray, U. S. Explor. Exped. [official ed.] 15 (1): 95–96, 1854, Atlas pl. 9, 1856; [public ed.] Botany, Phanerogamia 1: 95–96, 1854, Atlas pl. 9, 1857.

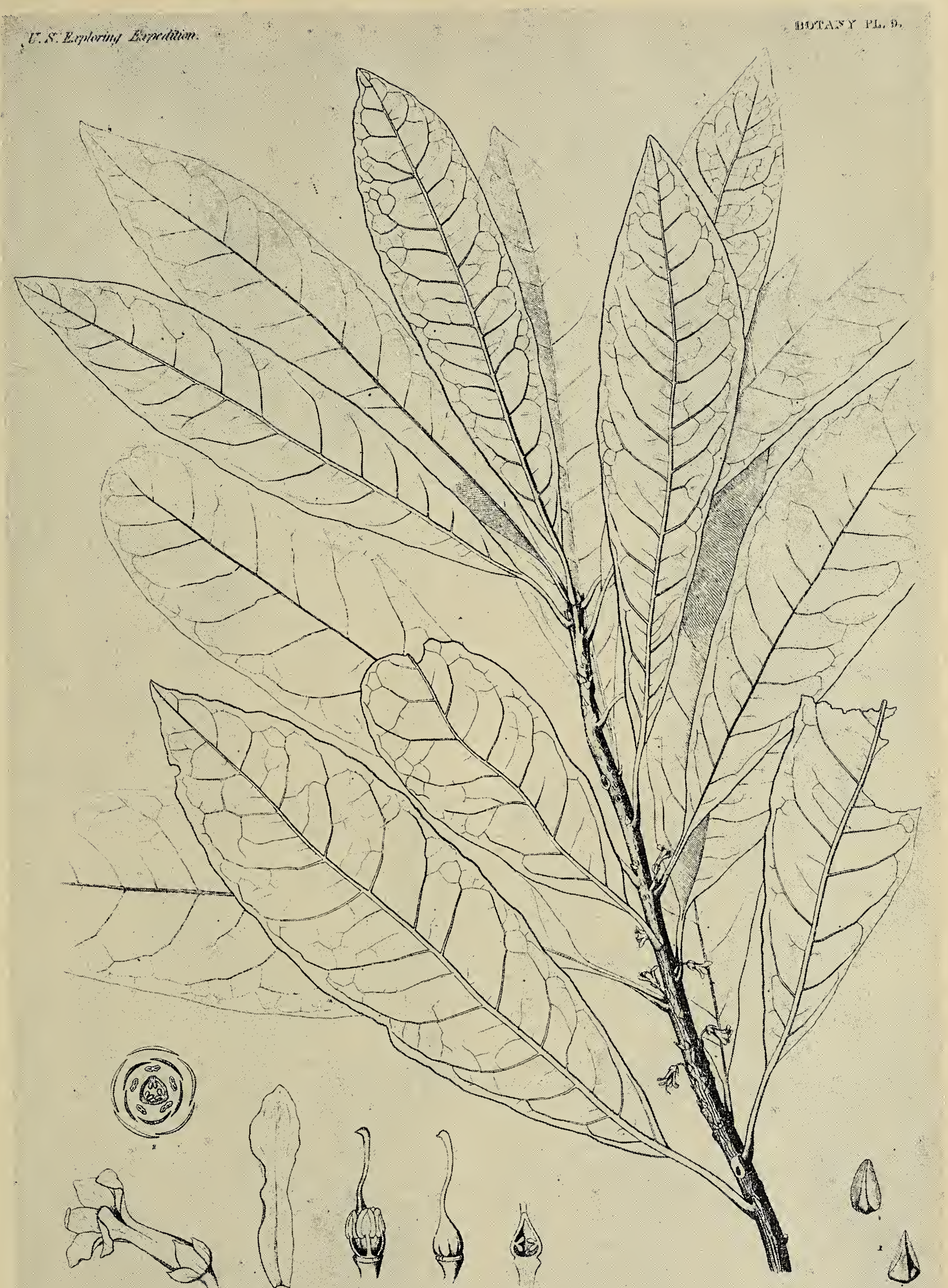
ILLUSTRATIONS: Figure 7.

DESCRIPTION OF ISOTYPE (US): Shrub (according to Pickering, 1854: 400, 6 feet high); glabrous, erect; older branches 5–8 mm. in diameter, its top broken, and from its apex arise 3 small secondary branches, bark of older twigs thick, corky, yellowish, with a few longitudinal fissures; leaf scars 3–5 mm. wide, suborbicular-shield-shaped, pale corky, with 3 bundle scars; twigs leafy for 1 cm., bearing 2–3 leaves, these ascending or diverging, not crowded; upper leafy stem 2.5–4 mm. in diameter, green, smooth but for the scattered wart-like developing patches of cork; nodes 3–10 mm. apart; stipules 3–4 mm. long, broadly deltoid, a little asymmetric, the thick, raised midrib much widened toward the base, the sides membranous, yellowish shading to brown at the edge; petioles 8–16 mm. long, channeled above, at base becoming thickened and corky; blades 11–16.3 cm. long, 30–65 mm. wide, oblanceolate or oblance-elliptic, subcoriaceous, finely reticulate veined, green above, yellowish green below, the apex obtuse, the base short cuneate, the margin subrepand; no flowers preserved.

Since this species is known only from the original collection, every effort was made to locate the type. It is not, as expected, in Washington. Instead, in that herbarium is an isotype, a smaller, sterile branch, broken at the top and with three weak shoots bearing broader and much shorter leaves than those described and illustrated by Gray from the better specimen then available. In the Gray Herbarium, in the fragmentary set of the Wilkes Expedition collections kept by Gray, there is a sheet of *I. longifolium* containing two short stem pieces, with only one good leaf 26.5 cm. long, 6 cm. wide, one broken leaf, one depauperate leaf, but no flowers or fruit. It has Isaac Sprague's pencil drawings, the originals for the published plate. No other isotype has been located in any herbarium, and the fine flowering branch, illustrated as the type, seems now to be lost. Since it is impossible to re-examine the type and make new detailed descriptions and drawings, a photographic copy of Gray's plate is here reproduced, and his description is here quoted. Since his first publication in 1852 contained only the Latin diagnosis, and as this is repeated verbatim in his fuller 1854 account, the latter is here quoted:

> "2. ISODENDRION LONGIFOLIUM, SP. NOV. (TAB. 9.)
>
> *I. glabrum; foliis subcoriaceis obovato-lanceolatis seu cuneato-oblongis in petiolum angustatis subrepandis; sepalis ovatis stipulisque laevibus; floribus in ramos crassos brevissime pedicellatis.*
>
> HAB. Kaala Mountains, Oahu, Sandwich Islands.
>
> Stems 6 feet high, with rather few very stout branches, roughened with the cicatrices of fallen leaves, and above with the persistent stipules. *Leaves* alternate, approximate at the summit of the branches, of a *coriaceous* texture, *entirely glabrous, as is the whole plant*, 6 to 8 inches long, 1½ to 2½ inches wide, *obovate-lanceolate*, varying from obovate-oblong to oblong-lanceolate, somewhat acute or acuminate, or rarely obtuse at the apex, below *tapering to an acute base*, veiny, and with the veinlets reticulated, the midrib very prominent underneath; the margins *obscurely repand-undulate*, or obsoletely and sparingly serrulate. Petioles ½ to 1½ inches long. *Stipules* geminate, subulate-triangular from a broad

FIG. 7. *Isodendrion longifolium.* A copy of Gray's Plate 9, habit×½; *1*, stipules×2; *2*, floral diagram×8; *3*, flower×4; *4*, petal×5; *5*, *6*, and *7*, stamens and pistil×2½. From type, Kaala Mts., Wilkes Expedition.



Isodendrion longifolium.

base, *glabrous*, carinate with a thickened axis, and with somewhat scarious margins, appressed, persistent long after the leaves have fallen. *Flowers* axillary, *solitary*, *on very short drooping pedicels*, which are bibracteolate next the base, and only one or 2 lines long. Calyx of 5 nearly distinct, ovate and glabrous sepals, quincuncially imbricated in aestivation, not at all produced at the base, scarcely a line long, persistent. Corolla hypogynous or obscurely perigynous, regular, apparently white, scarcely 3 lines long; petals 5, linear-spatulate, connivent for two-thirds of their length into a tube, the upper and dilated portion spreading, convolutely imbricated in aestivation, as in *Violeae*, marcescently persistent. Stamens 5, hypogynous or obscurely perigynous, alternate with the petals and much shorter than they, scarcely exceeding the ovary, all similar, entirely unconnected, glabrous. Filaments subulate-linear, flattened, about the length of the anthers which terminate them, destitute of any dorsal or terminal appendages. Anthers oblong, inappendiculate, exactly like those of the foregoing species. Disk none. Ovary, ovules, style, stigma, &c., nearly as in the foregoing species. Mature fruit not seen.—The leaf-bearing and flowering branches are about a quarter of an inch in diameter: the flowers are small and inconspicuous.

PLATE 9.—ISODENDRION LONGIFOLIUM. Fig. 1. Stipules, front and back view, enlarged. 2. Diagram of the flower. 3. A flower, enlarged. 4. A petal, more enlarged. 5. Stamens and pistil, magnified. 6. The same after removal of the stamens. 7. Vertical section of the ovary, magnified."

From measurements given in Gray's text and after comparison with his other two species and their illustrations, it is deduced that his habit sketch is magnified×1; fig. 1, ×4; fig. 2,×16; fig. 3,×8; fig. 4,×10; figs. 5, 6, and 7,×5. Our Figure 7 reproduces Gray's at ½ his scale of magnification.

For a discussion of the type locality, see the present treatment of *I. pyrifolium*.

TYPE: "Kaala Mountains, Oahu, Sandwich Islands," U. S. Exploring Expedition under *Capt. Wilkes* (Isotypes seen: GH, US).

The collector, Pickering, stated (1854: 400) that the flowers were "inconspicuous, greenish."

The species was obviously named from the Latin *longus*, long; and the Latin *folium*, leaf.

8. ***Isodendrion Lydgatei*** sp. nov.

ILLUSTRATIONS: Figure 8.

DIAGNOSIS TYPI: Frutex, ramis 3 mm. diametro, cortice brunneo glabro laevi sed asperato a stipulis persistentibus, cicatricibus 1.5–2.2 mm. latis rotundato-scutelliformibus pallide brunneis, fasciculis 3, ramulis foliosis 5–10 mm. longis 2 mm. diametro glabris viridibus plerumque a stipulis aggregatis occultantis 4–5 folias in fasciculem ferrentibus, nodis 1–14 mm. plerumque 1 mm. distantibus, stipulis 2.3–3.5 mm. longis 1.1–1.9 mm. latis oblique deltoideo-lanceolatis vel oblique lanceolatis stramineis marginibus membranaceis ciliolatis sed jam erosis carina incrassata cartilaginea longe durantibus, petiolis 1–2.5 mm. longis validibus anguste alatis, laminis 5–8 cm. longis 18–30 mm. latis subcoriaceis glabris oblongo-oblanceolatis obtusis minute nervosis contortis elevatis marginibus minime sinuatis, floribus solitariis axillaribus, pedunculis 1 mm. longis bracteatis, pedicellis 1 mm. longis, sepalis 3–3.3 mm. longis 0.9–1.2 mm. latis mediocrite vel anguste deltoideo-lanceolatis 3-nervosis glabris subviridibus chartaceis sed marginibus membranaceis ciliolatis, petalis inaequalibus, petala inferiora 7.5 mm. longa 1.2 mm. lata (postquam bullanda) ungue 5.8 mm. longo 1.2 mm. lato ligulato 3-nervato infra membranaceo tertia exteriore crassa carnosa et profunde canaliculata, limbo 1.7 mm. longo 1.5 mm. lato ovali carnoso opaquo, petalis lateralibus 7.2 mm. longis unguibus 5 mm. longis 1.2 mm. latis membranaceis 3-nervatis subligulatis sed in medio latioribus ad apicem canaliculatis, limbis 2.2 mm. longis 1.3 mm. latis ellipticis semiopaquis, petalis superioribus 6.6 mm. longis unguibus 4.7 mm. longis 3-nervatis ligulatis membranaceis, limbis 1.9 mm. longis 1.2 mm.

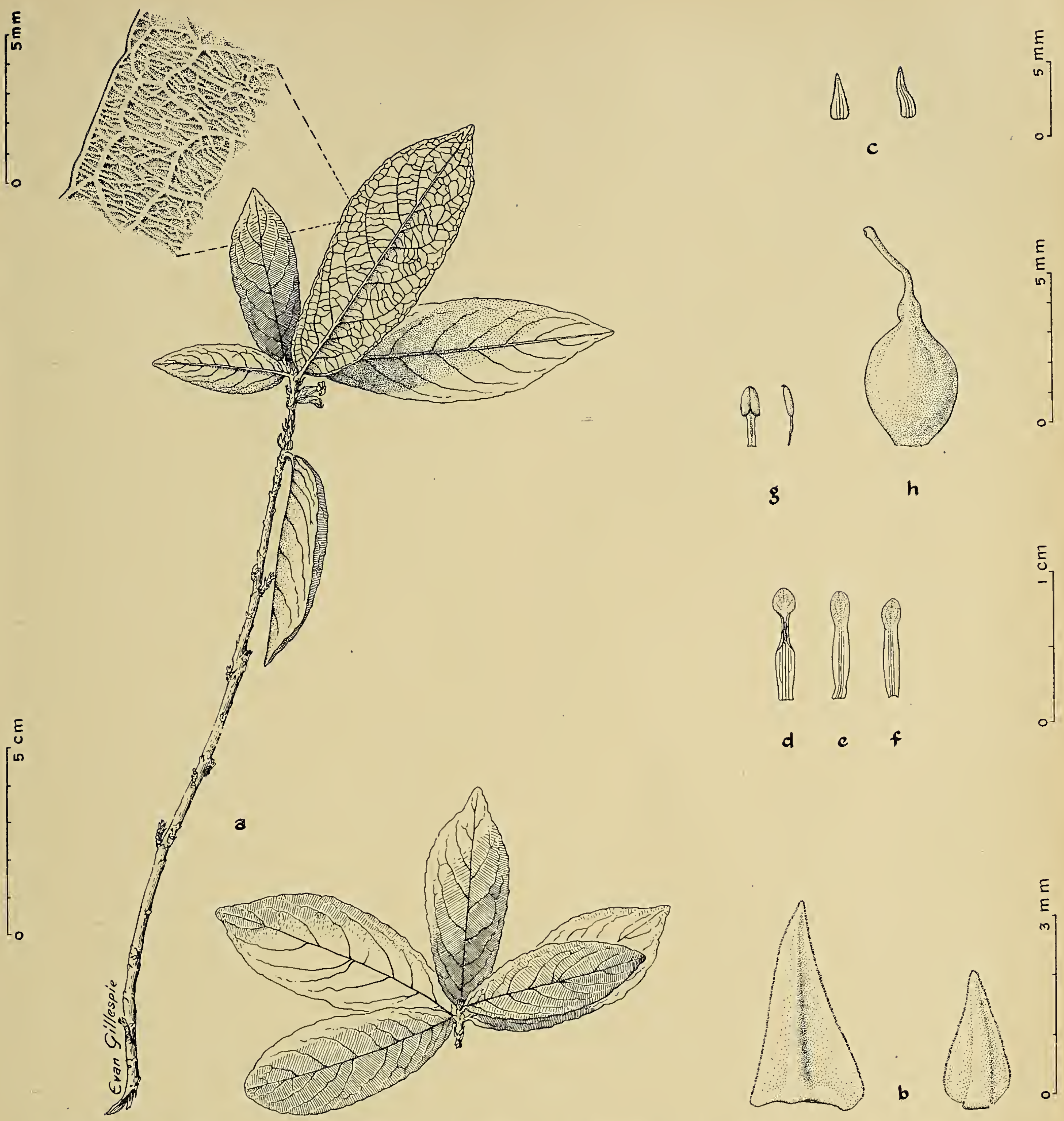


FIG. 8. *Isodendrion Lydgatei. a,* Habit×½; *b,* stipules×8; *c,* sepals×2; *d,* lower petal×2; *e,* lateral petal×2; *f,* upper petal×2; *g,* lower stamen×4; *h,* pistil×4. From the type, Manoa and Wailupe, Hillebrand & Lydgate.

latis ellipticis semiopaquis, staminibus subaequalibus sed superioribus minoribus et inarmatis, staminibus inferioribus 2 mm. longis, filamentis 1 mm. longis ligulatis lateribus subtilibus sed nervo in medio incrassato et in pagina exteriora glandulosa, antheris 1 mm. longis 0.6 mm. latis oblongo-ovatis subsagittatis, ovario vetustiori 5 mm. longo ovoideo 3-lobato, stylo 2.9 mm. longo filiforme, stigmate obliquo parvi crateriformi penicillati, fructu ignoto.

DESCRIPTION OF ALL SPECIMENS EXAMINED: Shrub; older branches 3–4 mm. in diameter, the bark brown, smooth, but the persistent rigid stipules giving it a rough, scaly look; leaf scars 1.5–2.2 mm. wide, rounded shield-shaped, pale brown, with 3 bundle scars; twig leafy for 5–10 mm., bearing 4–5 leaves in a close cluster; upper leafy stem 2 mm. in diameter, glabrous, greenish, largely concealed by the crowded stipules; nodes 1–14 mm., commonly 1 mm., apart in the leafy section; stipules 2.3–3.5 mm. long, 1.1–1.9 mm. wide, obliquely deltoid-lanceolate or obliquely lanceolate, straw-colored, the margins membranous, closely ciliolate, soon eroding, the midrib prominent, thickened, raised, cartilaginous and long persisting; petioles 1–2.5 mm. long, stout, glabrous, narrowly winged; blades 5–9 cm. long, 18–30 mm. wide, subcoriaceous, glabrous, oblong-oblanceolate, obtuse, the base elliptic-rounded, then short decurrent on the petiole, the surfaces finely and intricately raised reticulate veined, the margin perceptibly low sinuate; flowers single, axillary; peduncles 1 mm. long, bracteate; pedicel 1 mm. long; sepals 3–3.3 mm. long 0.9–1.2 mm. wide, deltoid-lanceolate or narrowly so, glabrous, greenish, chartaceous except at the membranous margins, 3-nerved, the margins ciliolate; corolla irregular, the lower three fourths of each petal forming a channel-like claw, the limb expanding and reflexing in anthesis; lower petal the longest but the lateral petals equal it in width, 7.5 mm. long, 1.2 mm. wide (when boiled), the claw 5.8 mm. long, 1.2 mm. wide, ligulate, membranous two thirds way from the base, 3-nerved from the base but the lateral nerves forking, in the upper third the tissue thick, fleshy and the margins upcurved forming a firm, deep channel, the limb 1.7 mm. long, 1.5 mm. wide, oval, fleshy, opaque; lateral petals 7.2 mm. long, the claw 5 mm. long, 1.2 mm. wide, membranous, subligulate but gradually widened at the middle, channeled at the tip, 3-nerved, limb 2.2 mm. long, 1.3 mm. wide, elliptic, semiopaque; upper petals 6.6 mm. long, the claw 4.7 mm. long, 1 mm. wide, ligulate, membranous, 3-nerved, limb 1.9 mm. long, 1.2 mm. wide, elliptic, semiopaque; stamens subequal, though the upper are slightly smaller and unarmed; lower stamens 2 mm. long, the filament 1 mm. long, ligulate, the sides thin, but the heavy vein bearing midway on the distal side an enlarged protruding glandular thickening; anthers 1 mm. long, 0.6 mm. wide, oblong-ovate, the bases of the anther sacs thickened and subsalient; ovary well past anthesis 5 mm. long, ovoid, 3-lobed; style 2.9 mm. long, terete; stigma lateral, small crateriform, penicillate; fruit unknown.

TYPUS: Oahu, Manoa and Wailupe, *William Hillebrand & J. M. Lydgate* (BISH), (st. lf. fl.).

SPECIMENS EXAMINED: Oahu, Wailupe, Ex Museo botanico Berolinensi, ex coll. *Hillebr.* (*J. F. Rock 17,062*), (BISH).

DISCUSSION: The data on these specimens need interpreting. The specimen to which Professor J. F. Rock added in his own hand his collection number 17,062 on the label of the College of Hawaii Herbarium, also has a printed label with "Ex Museo botanico Berolinensi" and in Rock's hand, "Isodendron laurifolium Gray, Oahu, Wailupe." On a visit to the Berlin herbarium in the spring of 1914, Rock was given clastotypes of nearly all of Hillebrand's new Hawaiian species, that is, of all that were large enough to divide. He also received fragments or duplicates of some of Hillebrand's other collections. These precious specimens came to the College of Hawaii; later they were transferred and are now in the B. P. Bishop Museum. This is the history of this one and many similar sheets. In this case it consists of a single detached good leaf, and two minute branch tips and two broken, tiny, depauperate leaves.

The second sheet, the one chosen as the type, has a different story. While living on Oahu, Dr. Hillebrand inspired several men to be his companions in exploring, helpers, or independent collectors. One such, when a young man, was the Reverend John M. Lydgate. He made many valuable contributions to Hillebrand's herbarium. Later, from Germany, Hillebrand sent to Lydgate named duplicates, not only of the ones that Lydgate collected, but of many others. These were labeled on loose tickets in Hillebrand's hand, giving the name and the locality. The writer has studied many of these specimens. Most of them lack the collector's name, and nearly all lack the date: Many of them include a mixture of material. It seems as if Hillebrand tried to send to Lydgate duplicates from as many collections as possible but that he frequently combined several under a single label, omitting some of the localities. Many sheets contain three specimens, and, in critical genera, they may represent two or three species. They are certainly authentic Hillebrand specimens, and the written label is in Hillebrand's hand, but it is often generalized and incomplete. When Hillebrand's own collection was mounted in Berlin, the original label was usually discarded. Years later Lydgate sold his set to Charles N. Forbes for the Bishop Museum. Forbes made the new printed second label, "Collected by Dr. William Hillebrand and J. M. Lydgate," and this was placed on all the Honolulu sheets, regardless of the identity of the actual collector. It is certain in many cases that Lydgate had nothing to do with the collecting and was merely the recipient and owner of the specimens years later. Forbes mounted the collection and inserted it in the Bishop Museum Herbarium. Though this Hillebrand and Lydgate specimen is placed in the same species, it may perhaps be different. Its single good leaf blade is 88×24 mm., or 3½ times as long as broad. Typical leaves of the Manoa and Wailupe, Hillebrand and Lydgate collection, are 2½ times as long as broad. The same ratio is seen in the ink sketch of the Wailupe and Manoa original specimen in the Berlin Herbarium, made by Rock in 1914. In his "Flora of the Hawaiian Islands" (p. 19) Hillebrand lists *I. laurifolium* only from his collection at "Ridges of Wailupe!" But apparently he had collected the plant at Manoa Valley also. If the fragment, obtained by Rock, of Hillebrand's Wailupe collection is characterized by the narrowly oblanceolate blades, then the broader-leaved one, labeled Manoa and Wailupe, may well have come from Manoa, and this seems a reasonable inference. Were the Wailupe specimen complete, one could settle its exact identity. But, as it consists of only a few fragments of herbage, and as it has a general similarity, it is for the time being classed as of the same species as the other Hillebrand collection from Manoa. Manoa and Wailupe Valleys are on the lee side of the southern end of the Koolau Range, Oahu, and are only 4 miles apart.

The species is named for the Reverend John Mortimer Lydgate (1854–1922) who, in his youth, was field companion and coöperator with Hillebrand in the botanical exploration of the Hawaiian Islands.

9. ***Isodendrion maculatum*** sp. nov.

ILLUSTRATIONS: Figure 9.

VERNACULAR NAME: "Aupaka."

DIAGNOSIS TYPI: Frutex 2 m. alta glaber, ramis erectis simplicibus 3–4 mm. diametro cortice griseo cum sulcis longitudinalibus paucis, cicatricibus 3–4 mm. latis pallidis suborbicularibus in summo minime concavis, fasciculis 3, nodis 2–30 mm. plerumque 10–20 mm. distantibus, ramulis 10–19 cm. longis cum 8–12 foliis adscendentibus in 45° et non aggregatis, stipulis 3–3.5 mm. longis paene symmetrici-deltoideis glabris carina incrassata marginibus brunneis membranaceis, petiolis 5–17 mm. longis, laminis 6.4–22 cm. longis 18–77 mm. latis firme chartaceis supra nigri-viridibus infra pallide viridibus oblanceolatis apice breve subacuminatis et late obtusi marginibus remote humiliter serrulatis excepta ad basim nervis elevatis reticulatis prominentibus praesertim infra, inflorescentibus axillaribus unifloris glabris, pedunculis 1 mm. longis, bracteis 1 mm. longis lanceolatis, pedicellis 2.5 mm. longis, sepalis 2–2.5 mm. longis lanceo-ovatis glabris subtilibus in centro obscuro-lineatis marginibus membranaceis pellucidis, petalis irregularibus glabris, petala inferiora 7.8 mm. longa (postquam bullanda) limbo 2.6 mm. longo 1.7 mm. lato ovali subcarnoso praesertim in parte basali, ungue 5.2 mm. longo 1.4 mm. lato in basi 5-nervoso membranaceo ad apicem firmo et profunde canaliculato, petalis lateralibus 7.6 mm. longis oblongo-spatulatis limbis 2.5 mm. longis 1.4 mm. latis anguste ovatis incrassatis et firmis praesertim ad basim, unguibus 5.1 mm. longis 1.5 mm. latis subtilibus et cum 2 nervis tenuibus adjectis, petalis superioribus 7.3 mm. longis oblongis obtusis limbis 2.3 mm. longis 1.2 mm. latis anguste ovali-oblongis ad basim incrassatis, unguibus 5 mm. longis 1.5 mm. latis anguste oblongis 5-nervosis in centro canaliculato incrassato marginibus amplis membranaceis, staminibus subaequalibus, filamentis 0.9 mm. longis, antheris 0.8–1 mm. longis 0.4 mm. latis obcuneatis obtusis apice connectivi minute apiculato, ovario 3 mm. longo ovoideo, stylo 3 mm. longo filiforme, stigmate orbiculare obliquo, capsulis 9–10 mm. longis ovoideis acuminatis a stylo rostratis rubro-maculatis profunde 3-lobatis, seminibus 2.9–3 mm. longis 2 mm. diametro obovoideis sublucidis obscure rubescenti-brunneo-maculatis apice truncato depresso.

DESCRIPTION OF ALL SPECIMENS EXAMINED: Shrub; 2 m. tall, glabrous, the branches erect, simple, older branches 3–4 mm. in diameter, bark gray, with a few longitudinal fissures; leaf scars 3–4 mm. wide, suborbicular, the top slightly concave, pale, with 3 bundle scars; nodes 2–30 mm., commonly 10–20 mm. apart; leafy branchlets 2–4 mm. in diameter, leafy for 10–19 cm., bearing 8–12 leaves that ascend, diverging at 45° from the stem and not crowded; stipules 2.5–3.5 mm. long, almost symmetrically deltoid, glabrous, the midrib thickened, the margins brown membranous; petioles 5–17 mm. long; blades 6.4–22 cm. long, 18–77 mm. wide, oblanceolate, firm chartaceous, above dark green, below pale green, the apex abruptly contracted and short subacuminate and broadly obtuse, the margin remotely low serrulate in the outer two thirds, the veins raised reticulate and prominent, especially below; inflorescences 1-flowered, axillary, glabrous; peduncles 1 mm. long; peduncular bracts 1 mm. long, lanceolate; pedicels 2.5 mm. long; sepals 2–2.5 mm. long, lance-ovate, glabrous, thin, the center dark lined, the membranous margins translucent; corolla glabrous, irregular, the lower two thirds of the petals forming a concave channel-like claw, the limb expanded and reflexing in anthesis; the lower petal slightly larger than the others, 7.8–9 mm. long (when boiled), the limb 2.6–2.7 mm. long, 1.7–1.8 mm. wide, oval, thickened and somewhat fleshy, especially in the lower third, reflexed and the apex subcucullate; claw 5.2–6.3 mm. long, 1.4–1.6 mm. wide, at base membranous and 5-nerved, towards the apex firm and deeply channeled; lateral petals 7.6–8.8 mm. long, oblong-spatulate, the limb 2.5–3.2 mm. long, 1.4–1.9 mm. wide, narrowly ovate, thickened and firm especially at base; claw 5.1–5.6 mm. long, 1.5–1.9 mm. wide, thin and with the broad margins membranous, strongly 3-nerved and with 2 more weak lateral nerves; upper petals 7.3–8 mm. long, oblong, obtuse, the limb 2.2–2.3 mm. long, 1.2–1.9 mm. wide, narrowly oval-oblong, thickened towards the base; claw 5–5.8 mm. long, 1.5–1.6 mm. wide, narrowly oblong, 5-nerved, the central strip thicker, the broad margin membranous; stamens subequal, filaments 0.9–1.3 mm. long; anthers 0.8–1 mm. long, 0.4 mm. wide, obcuneate-oblong, obtuse, the apex minutely apiculate; sepals 4.5–4.7 mm. long, 1.6–2.4 mm. wide, deltoid ovate and obtuse to deltoid-lanceolate, acute, the body greenish and 5–7-nerved, the margin membranous, ciliate above; corolla glabrous, irregular, the lower two thirds of the petal forming a concave, channel-like claw, imbricate laterally, enfolding the neighboring ones and together imitating a corolla tube, the limb expanded and reflexing in anthesis; lower petal slightly longer than the rest, 9 mm. long (when boiled), the limb 2.7 mm. long, 1.8 mm. wide, almost oblong, thickened and somewhat fleshy, the apex subcucullate; claw 6.3 mm. long, 1.6 mm. wide, oblong, membranous, essentially flat, 3-nerved; lateral petals 8.8 mm. long, spatulate, slightly constricted at apex of claw, the limb

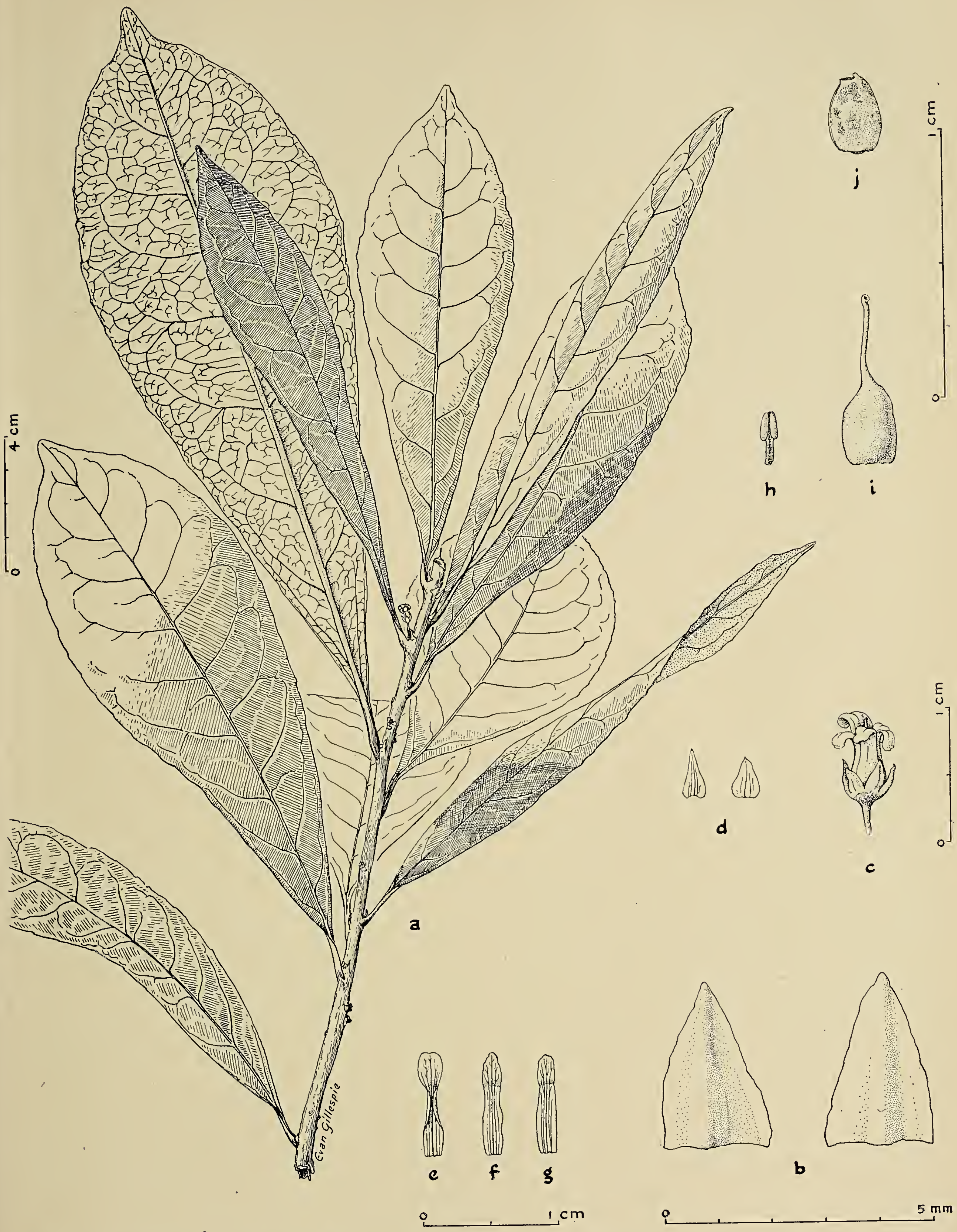


FIG. 9. *Isodendrion maculatum.* *a*, Habit×½; *b*, stipules×8; *c*, flower×2; *d*, sepals×2; *e*, lower petal×2; *f*, lateral petal×2; *g*, upper petal×2; *h*, stamen×4; *i*, pistil×4; *j*, seed×4. From the type, Hanakapiai, St. John *et al.* 10,988.

3.2 mm. long, 1.9 mm. wide, oval, emarginate, thickened, claw 5.6 mm. long, 1.9 mm. wide, ligulate, essentially flat, membranous, 3-nerved; upper petals 8 mm. long, oblong-spatulate, obtuse, the limb 2.2 mm. long, 1.9 mm. wide, oval, thickened, the claw 5.8 mm. long, 1.6 mm. wide, ligulate, membranous, essentially flat, 5-nerved; stamens subequal, filaments 1.3 mm. long, ligulate but narrowed above, anthers 0.8 mm. long, cuspidate at apex, the anther sacs ellipsoid, diverging towards the base; ovary 2 mm. long, ovoid; style 3.8 mm. long, subulate; stigma broad hippocrateriform; ovary 3 mm. long, ovoid; style 3 mm. long, filiform; stigma oblique, circular; capsules 9–10 mm long, ovoid, acuminate and beaked by the style, red maculate, deeply 3-lobed; seeds 2.9–3 mm. long, 2 mm. wide, obovoid, dark reddish-brown maculate, a little shiny, the apex truncate, depressed.

TYPUS: Kauai, Hanakapiai, Napali Coast, in woods, 800 ft., Jan. 2, 1931, *H. St. John et al. 10,988* (BISH), (st. lf. fl. fr.).

SPECIMENS EXAMINED: Kauai, Wahiawa Mts., *J. M. Lydgate* (BISH), (st. lf. fl.); ex Museo botanico Berolinensi, *Knudsen 196* (BISH), (lf. fl.).

There are slight differences between the two latter collections and the type which came from the north, or Napali, coast of Kauai. The specimen from the Wahiawa Mountains, collected by Lydgate, consists of small snips from a shrub, but when assembled these show the stem, stipules, leaves, flowers, and young fruit. Only the sepals differ slightly in having a few ciliolations towards the tip. All other parts match well those of *I. maculatum*, hence it seems best to keep it within that species.

The collection, *Knudsen 196*, consists of fragments given to Rock from the Hillebrand collection in Berlin. It contains five loose blades and one loose flower. It was identified by Hillebrand as *I. longifolium* and so cited in his flora (1888: 19). The blades are similar in texture and general outline to the oblanceolate, undulate ones of *I. longifolium*, but they are only 5.4–9.5 cm. long, far below the dimensions of the former, and are crenate instead of merely undulate. The flower differs from those of *I. maculatum* only in having the calyx lobes slightly longer and narrower and glabrous. Rock studied the original sheet when in Berlin in 1914 and made an ink sketch of it. This shows a large plant with six leaves fully outlined, 11–16 cm. long, 30–42 mm. wide, linear-oblanceolate, and like those of *I. maculatum*. Rock also listed as identical another specimen, *Knudsen 3*.

In view of the fragmentary nature of the material and the slight differences, the specimens collected by Knudsen and by Lydgate are, for the present, included within the population limits of *I. maculatum*.

The vernacular name "aupaka" is recorded for *I. pyrifolium* Gray by Hillebrand (1888: 18) and is the only published record of a common name for any of the species. Though Hillebrand was a very accurate man and his flora is a scientific model, there seems to be an error at this point. Recently it was learned that, in the library of the Hawaii National Park at Kilauea, there was a copy of H. Mann's *Enumeration of Hawaiian Plants* (1867) bearing Hillebrand's signature. As shown by the book plate and the library stamp and accession number 25,290, this copy was once in the library of the United States Geological Survey in Washington. Later it was removed and the entry cancelled, and it was sold, probably as a duplicate. As the son, William F. Hillebrand, lived in Washington and was long a staff member of the U. S. Geological Survey, it appears that Hillebrand's annotated copy passed to his son, to the Geological Survey, then was sold in 1935 to the Hawaii National Park. This copy has recently been loaned to the Bishop Museum, and there it has been collated. On the front cover Hillebrand wrote his name in ink, and throughout the pamphlet made additions in the margin in ink or pencil. These are mostly to supply the Hawaiian vernacular names, none of which had been included by Mann. There are also some notes, including some on geographic occurrence. Well placed, even with No. 14, *Isodendrion longifolium* Gray, there is the marginal note in pencil in Hillebrand's hand, "Aupaka (Kauai)." This is at variance with Hillebrand's own printed record of the name "aupaka" for *I. pyrifolium* which is No. 13, the species just above in Mann's *Enumeration.* It could be supposed that his hand had slipped and the words were written a little too low on the page, but he gave Kauai as the locale of the name. Gray had described *I. pyrifolium* from Oahu alone, then Hillebrand, using a wider species concept, recorded it from Oahu, Lanai, Maui, and (by implication) from Hawaii, and Niihau also. In this present monographic treatment only the Oahu specimens remain in *I. pyrifolium*, while the specimens from other islands are allocated to different species. The only Kauai collection known to Hillebrand was by Knudsen, and he classified that as the same as the Oahu species *I. longifolium.* The Knudsen specimen is here identified as *I. maculatum.* Mr. Valdemar Knudsen of Waiawa, Kauai, was one of Hillebrand's most active collectors and coöperators. He made pioneer explorations of the forests and mountains of Kauai. Since we have, in Hillebrand's own writing, the record that "aupaka" was the name of *Isodendrion* on Kauai, it is apparent that this name should go with the Knudsen collection from Kauai. Hence, the vernacular name is transferred to the new *I. maculatum.*

The species is named from the Latin, *maculatus*, spotted, in allusion to the red-spotted fruits.

10. *Isodendrion molokaiense* sp. nov.

ILLUSTRATIONS: Figure 10.

DIAGNOSIS TYPI: Frutex, ramis 3–5 mm. diametro cortice griseo in longitudinem sulcatis a nodis et stipulis asperratis, cicatricibus 1.2–1.8 mm. latis depresso-cordatis, fasciculis 3, ramulis 5–10 cm. longis 1–2 mm. diametro nigri-rubro-viridibus puberulentis parte superiore a stipulis imbricatis clausis 10–18 foliis aggregatis ferrentibus, nodis 2–12 mm. distantibus, stipulis 4.2–5 mm. longis 2.3–2.5 mm. latis deltoideis vel oblongo-deltoideis carina incrassata et ad basim distenta albi-adpressi-puberulenti ad apicem lateribus membranaceis glabris in sicco brunneis marginibus dense pilosuloso-ciliatis, petiolis 4–9 mm. longis 0.5–0.8 mm. diametro albi-adpressi-puberulentis, laminis 22–52 mm. longis 16–26 mm. latis firme chartaceis ovatis acutis in basi rotundatis supra nigri-viridibus et sparse puberulentis in nervo medio infra pallide viridibus et minute reticulatis sparse albi-adpressi-puberulentis, inflorescentiis 1-floriferis axillaribus, pedunculis 4 mm. longis adpressi pilosulis in apice cum 2 bracteis 3.5–4.5 mm. longis stipulaceis, pedicellis 2 mm. longis adpressi-pilosulis, sepalis 4–4.6 mm. longis oblongo-ovatis carina et nervo medio dense albi-adpressi-pilosuli ad apicem excurrenti marginibus pallidis vel brunneis pilosuloso-ciliatis, petalis irregularibus, petala inferiora 10 mm. longa (postquam bullanda) limbo 2.8 mm. longo 2.5 mm. lato late ovali carnoso sed nervis evidentibus apice cucullato recurvato extra dense adpressi-albi-pilosuloso, ungue 7.2 mm. longo 2.2 mm. lato oblongo sed ad basim membranaceo diminuendo 5-nervoso ad apicem carnosiori extra adpressi-pilosuloso, petalis lateribus 9.5 mm. longis oblongo-spatulatis extra adpressi-pilosulosis, limbis 2.7 mm. longis 2.4 mm. latis ovatis carnosis, unguibus 6.8 mm. longis 1.9 mm. latis 5-nervosis oblongis sed ad basim diminuendis membranaceis, petalis superioribus 9.3 mm. longis extra pilosulosis, limbis 2.6 mm. longis late ovalibus carnosis ad basim subcontractis, unguibus 6.7 mm. longis oblongis sed ad basim diminuendis membranaceis 3-nervosis, staminibus inaequalibus superioribus minoribus et inarmatis et eglandulosis, staminibus inferioribus cum filamentis 1.4 mm. longis subulatis in pagina exteriore glandulosis, antheris 1.2 mm. longis 0.9 mm. latis ovatis connectivo in apice cum aculeo

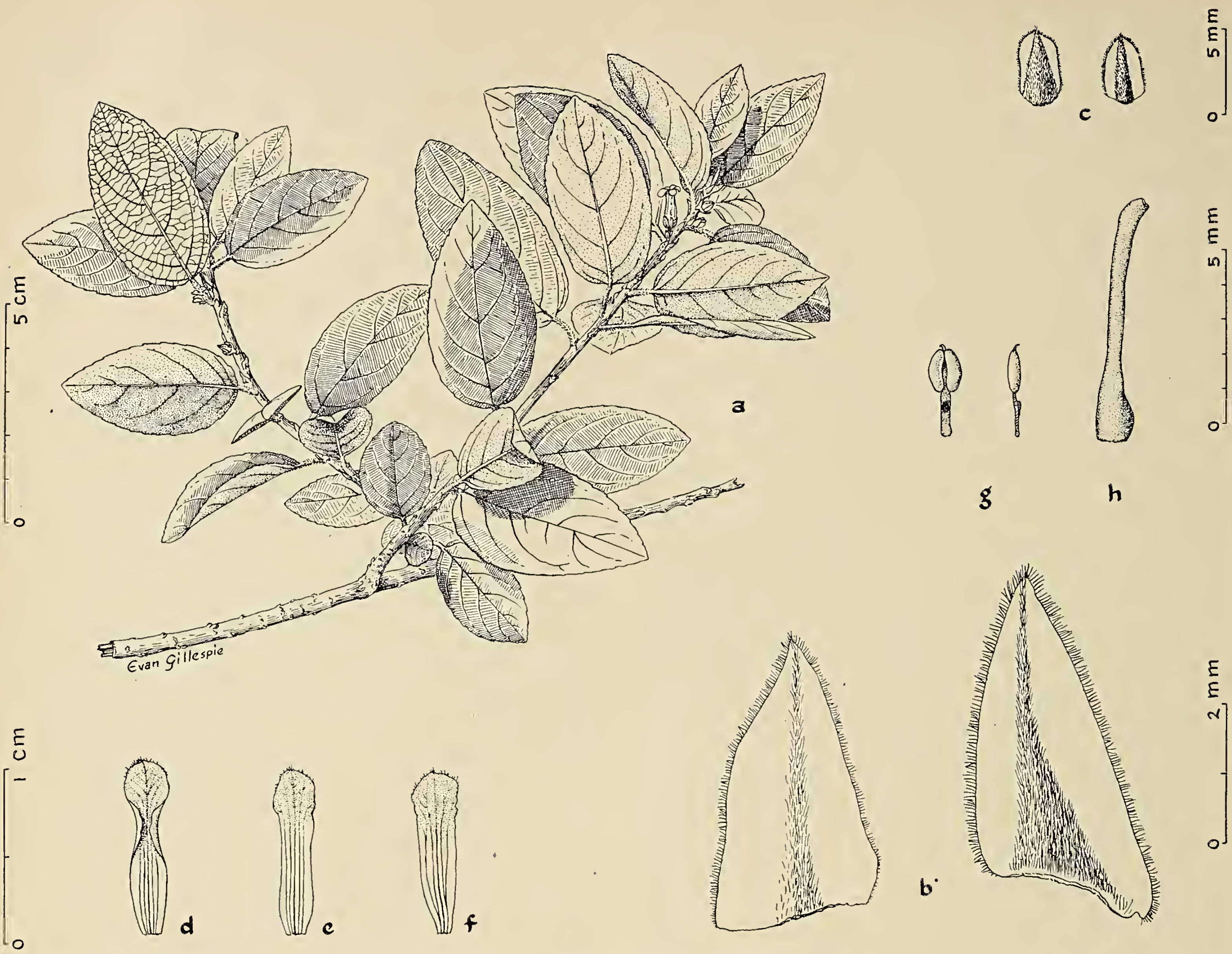


FIG. 10. *Isodendrion molokaiense*. *a*, Habit×½; *b*, stipules×8; *c*, sepals×2; *d*, lower petal×2; *e*, lateral petal×2; *f*, upper petal×2; *g*, lower stamen×4; *h*, pistil×4. From the type, Molokai, Remy 533.

0.1 mm. longo, ovario 1.5 mm. longo oblique lanceoloideo glabro, stylo 5.7 mm. longo tereto pallido glabro, stigmate orbiculari obliquo; fructu ignoto.

DESCRIPTION OF TYPE: Shrub; older branches 3–5 mm. in diameter, the bark gray, longitudinally ridged, roughened by prominent nodes and persistent stipular bases; leaf scars 1.2–1.8 mm. wide, depressed obcordate; bundle scars 3; twigs leafy for 5–10 cm., bearing 10–18 leaves, these crowded; upper leafy stem 1–2 mm. in diameter, dark reddish green, puberulent, at least the upper part concealed by the imbricate stipules; nodes 2–12 mm. apart; stipules 4.2–5 mm. long, 2.3–2.5 mm. wide, deltoid to oblong-deltoid, the midrib much widened below, thick and densely appressed white pilosulous distally, the sides membranous, drying brown, glabrous, the margins closely pilosulous ciliate; petioles 4–9 mm. long, 0.5–0.8 mm. in diameter, appressed white puberulent; blades 22–52 mm. long, 16–26 mm. wide, firm chartaceous, ovate, acute, the base rounded, above dark green and puberulent, with a few hairs appressed along the midrib, below pale green and finely reticulate, sparsely appressed white puberulent; inflorescences 1-flowered, axillary; peduncle 4 mm. long, appressed pilosulous, at apex with two stipule-like bracts 3.5–4.5 mm. long; pedicel 2 mm. long, appressed pilosulous; sepals 4–4.6 mm. long, oblong ovate, the very heavy, triangular midrib densely white appressed pilosulous and excurrent as an acute tip, the pale or brownish margins pilosulous ciliate; corolla irregular, the lower two thirds of the petals forming a concave channel-like claw, the limb reflexing in anthesis; the lower petal the largest, 10 mm. long (when boiled), the limb 2.8 mm. long, 2.5 mm. wide, broadly oval, thickened and fleshy but the pinnate venation visible, the apex cucullate recurved, densely appressed white pilosulous without; claw 7.2 mm. long, 2.2 mm. wide, oblong but narrowing towards the base, 5-nerved from the base, membranous below, fleshy toward the limb, the back appressed pilosulous; lateral petals 9.5 mm. long, appressed pilosulous without, oblong spathulate, the limb 2.7 mm. long, 2.4 mm. wide, broad ovate, fleshy; claw 6.8 mm. long, 1.9 mm. wide, 5-nerved, oblong but narrowed at base, membranous; upper petals 9.3 mm. long, pilosulous without, the limb 2.6 mm. long, broadly oval, fleshy, little contracted at base; claw 6.7 mm. long, oblong but narrowed at base, membranous 3-nerved at base; stamens unequal, the upper ones smaller and unarmed and glandless; lower stamens with filaments 1.4 mm. long, subulate, with a thickened dorsal gland; anthers 1.2 mm. long, 0.9 mm. wide, ovate, bearing a curved apical prickle 0.1 mm. long; ovary 1.5 mm. long, obliquely lanceoloid, glabrous; style 5.7 mm. long, terete, pale glabrous; stigma oblique, orbicular; fruit unknown.

TYPUS: Molokai, 1851–1855, *J. Remy 533* (P), (st. fl. lf.).

The species is named with reference to its occurrence on the island of Molokai.

11. **Isodendrion pyrifolium** Gray, Amer. Acad. Arts and Sci., Proc., 2: 324, 1852; Gray, U. S. Explor. Exped. (official ed.) 15 (1): 93–95, 1854, Atlas pl. 8, 1856; (public ed.) Botany, Phanerogamia 1: 93–95, 1854, Atlas pl. 8, 1857.

ILLUSTRATIONS: Figure 11.

DESCRIPTION OF TYPE SPECIMEN: Shrub; "about 6 feet high," freely branched with several ascending secondary branches; older branches 3 mm. in diameter, the bark reddish brown, smooth but with persistent, appressed white puberulence, and rough from the persistent stipules; leaf scars 2–2.2 mm. wide, obovate-shield-shaped, pale with 3 bundle scars; nodes 3–15 mm., commonly 3–10 mm. apart; leafy branchlets 1.5–3 mm. in diameter, leafy for 5–20 mm., bearing 4–8 leaves in a terminal crowded plume, the leaves mostly ascending; this upper stem closely appressed white puberulent but stem and hairs both largely concealed by the crowded, imbricate stipules; stipules 4–4.7 mm. long, narrowly deltoid, slightly oblique, the heavy raised midrib densely appressed puberulent, the sides brown membranous and ciliolate; petioles 5–9 mm. long, slender, closely appressed white puberulent; blades 2.5–5.4 cm. long, 12–28 mm. wide, chartaceous, above dark green, subglabrate except for the veins towards the base, below paler and appressed puberulent, ovate or even elliptic, the margin subentire or on the larger leaves barely subserrulate, the veins not conspicuous; flowers axillary, single; peduncle 4–6 mm. long, canescent, bracted; pedicels 3–4 mm. long, canescent; sepals 3.9–4.1 mm. long, 1.5–1.7 mm. wide, broadly lanceolate, 3-nerved within the central large, thickened, closely ascending hirsutulous area, the margins membranous; corolla irregular, the lower two thirds of the petals forming a channel-like claw, the limb expanding and reflexing in anthesis; lower petal the largest 8.2 mm. long (when boiled), 2.1 mm. wide, contracted two thirds way from the base, both the claw and the limb elliptic, the upper two thirds fleshy and thickened, from the base 5-nerved, claw 5 mm. long, 2.1 mm. wide; lateral petals 7.8 mm. long, 2 mm. wide, scarcely contracted at the apex of the fleshy claw, 3-nerved from the base; upper petals 7.1 mm. long, 1.5 mm. wide, the claw broad ligulate, 3-nerved from the base, the claw slightly broader and oval and somewhat fleshy; stamens equal 1.9 mm. long; filaments subulate; anthers 1.1 mm. long, 0.7 mm. wide, the cells narrowly oblong, diverging at base, the apex barely minutely apiculate; ovary 1 mm. long, narrowly ovoid, 3-angled; style 4.5 mm. long, the lower half subulate, the upper half

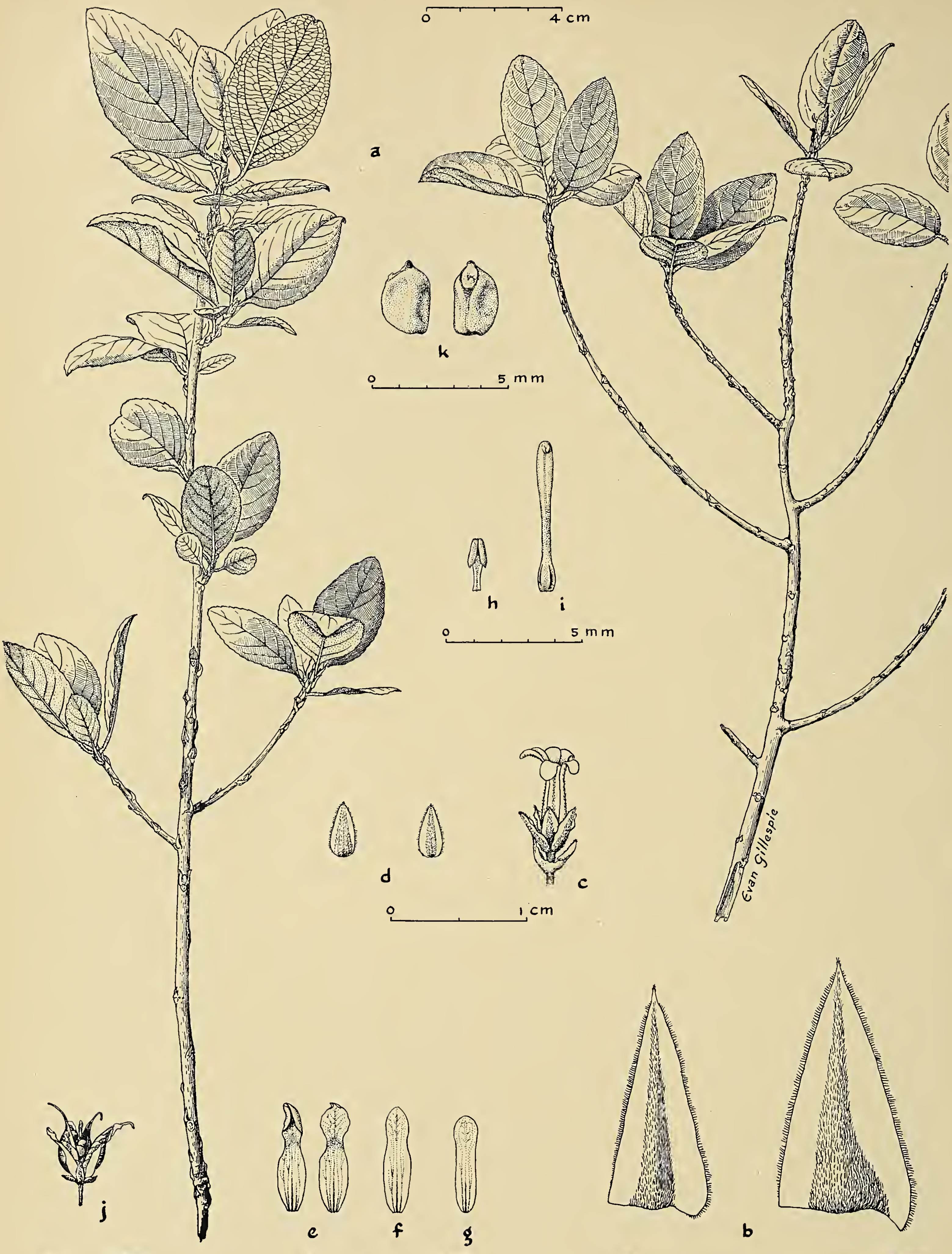


FIG. 11. *Isodendrion pyrifolium*. *a*, Habit×½; *b*, stipules×8; *c*, flower×2; *d*, sepals×2; *e*, lower petal×2; *f*, lateral petal×2; *g*, upper petal×2; *h*, stamen×4; *i*, pistil×4; *j*, capsule×1; *k*, seeds×4. From the type, Oahu, Wilkes Expedition.

widened and inflated; stigma lateral, obovate.

TYPE: Sandwich Islands, Oahu, U. S. Exploring Expedition under *Capt. Wilkes* (US), (st. lf. fl. fr.). Type examined. Also isotype (GH), (st. lf. fr.). Pickering (1854: 400) gave further details, "in a ravine on the southern flank of Mauna Kaala at an elevation of a thousand feet . . ."

Known only from the type collection. In Gray's second publication on it—that in the United States Exploring Expedition series—he gave more details. As to the locality, he added (1854: 93): "Wooded portion of the Kaala Mountains, Oahu, Sandwich Islands." This species, it seems, has not been collected subsequently, as all of the other records given by Hillebrand (1888: 18) are here referred to other species. Gray gives a lengthy description, which is not quoted here as it seemed best to make a new, detailed, independent description. Gray says (1854: 94) of the petals that "They are all alike in size and shape, about 4 lines long . . ." That statement was inaccurate, as can be noted by comparing the enlarged drawings of the petals (our Fig. 11), prepared from the type specimen.

The three new species of *Isodendrion* described by Gray in 1852 were all cited as from the Kaala Mountains, Oahu, but in the U. S. Exploring Expedition series in 1854, he expanded (1854: 93) the habitat for *I. pyrifolium* only, to "Wooded portion of the Kaala Mountains." This and the other two species were apparently collected on November 4, 1840. More data can be gleaned from the volume by Pickering who was one of the collectors (1854: 400). In the Violaceae they collected on Oahu only the three species of *Isodendrion* and *Viola Chamissonis* Ging. Pickering (1854: 386), speaking of the drier mountain range near "Waianai" [Waianae], says "High up along this Leeward flank of the Mauna Kaala ridge, Mr. Brackenridge and myself met with various remarkable plants that were not seen elsewhere: as . . . the remarkable Violaceous shrubs, with flowers arising from the old wood . . ." Then (p. 399) he lists them: "Viola (No. 1). Normal, though becoming a shrub, upright, and one to two feet high; leaves ovate, cordate at base, long pointed. On 'Mauna Kaala,' within the Leeward portion of Oahu, Brackenridge." [This is surely *V. tracheliifolia* Ging., which is common on the ridge near Mt. Kaala.]

On page 400 Pickering lists three species of another violaceous genus [*Isodendrion*].

> "Gen. Violac., (No. 1). A shrub, six feet high; leaves oblong-ovate, serrulate. Growing in a ravine on the southern flank of Mauna Kaala, at the elevation of a thousand feet; (pointed out to me by Mr. Brackenridge).
>
> ——— ——— (No. 2). A shrub, six feet high; large obovate coriaceous leaves, six inches by two; flowers small, inconspicuous, and greenish, arising along the stem from the old wood, short pet. Growing in the same locality, on the Southern flank of Mauna Kaala; (pointed out to me by Mr. Brackenridge).
>
> ——— ——— (No. 3); habit of the last, but the leaves smaller, subsessile, with few crenatures. Growing in the same locality, on the Southern flank of Mauna Kaala; (pointed out to me by Mr. Brackenridge)."

This enumeration contains enough descriptive material to make possible the identification of these numbered Violaceae as: No. 1, *Isodendrion pyrifolium* Gray; No. 2, *I. longifolium* Gray; No. 3, *I. laurifolium* Gray.

The vernacular name "aupaka" given by Hillebrand (1888: 18) is discussed under *I. maculatum* and here transferred to that species.

The specific name was obviously coined from the generic name *Pyrus*, the pear; and the Latin *folium*, leaf, indicating a resemblance between its leaves and those of the pear tree.

12. *Isodendrion Remyi* sp. nov.

ILLUSTRATIONS: Figure 12.

DIAGNOSIS TYPI: Frutex, ramis pluribus adscendentibus glabratis 2–4 mm. diametro cortice laevi griseo, cicatricibus 1.5 mm. latis depresso-obcordatis, fasciculis 3 inferiore majori, ramulis a stipulis persistentibus asper-

ratis, ramulis foliferis 3–20 mm. longis cortice adpressi-pilosulo sed plerumque a stipulis imbricatis clausis, foliis 5–8 adscendentibus vel divergentibus, stipulis 5–5.5 mm. longis oblique lanceolatis acuminatis marginibus ab initio ciliolatis posthac glabratis vel subglabratis carina incrassata cartilaginea dense adpressi-albi-pilosula, petiolis 6–10 mm. longis adscendenti-albi-pilosulis, laminis 25–60 mm. longis 17–32 mm. latis ovalibus vel lanceo-ovalibus chartaceis infra in nervis adpressi-pilosulis et remote pilosulis in intervallis supra glabris excepta nervo medio minute adpressi-pilosulis apice subacuti marginibus minute depresso-crenatis vel apiculato-crenatis, inflorescentiis adpressi-puberulentis axillaribus solitariis, pedunculis 3–6 mm. longis, bracteis 2 mm. longis ovatis, pedicellis 2–4 mm. longis, floribus divergentibus, sepalis 4–5 mm. longis ovato-lanceolatis 1.5 mm. latis nervo medio 0.5 mm. lato eo et regio mediale dense adpressi-albi-pilosulo lateribus membranaceis bruneis glabris marginibus ciliolatis, petalis inaequalibus extra albi-hirsutulis, petala inferiora 14.5 mm. longa (postquam bullanda) spatulata limbo 2.4 mm. lato carnoso, ungue 1.8 mm. lato, petalis lateralibus 13 mm. longis anguste spatulatis, limbis 0.9 mm. latis, unguibus 1.4 mm. latis carnosis canaliculatis marginibus angustis membranaceis, petalis superioribus 12.2 mm. longis anguste spatulatis, limbis 4.2 mm. longis, 1.7 mm. latis carnosis, unguibus 1.8 mm. latis, filamentis 1.3 mm. longis ligulatis, antheris 1 mm. longis saccis linearibus infra divergentibus, staminibus duobus inferioribus in apice connectivo cum seta 0.3 mm. longa, ovario 6 mm. longo 2.8 mm. diametro ovoideo glabro, stylo 5 mm. longo subulato, ad apicem deflexo, stigmate semigloboso, capsulis 12 mm. longis 7 mm. latis brunneis cartilagineis verrucosis reticulatis, valvis tribus anguste canaliculatis sed in dorso rotundatis, quisque 4-seminiferis, seminibus non visis.

DESCRIPTION OF TYPE: Shrub; the several ascending branches glabrate, the bark smooth, gray, 2–4 mm. in diameter; leaf scars 1.5 mm. wide, depressed obcordate; bundle scars 3, the lower one large, the two lateral ones much smaller; small twigs, even well-below the leaves, rough from the stiff, persistent stipules; young branchlets leafy for a distance of only 3–20 mm., the bark appressed pilosulous but this almost completely concealed by the overlapping stipules; the leaves 5–8, ascending or diverging in a terminal plume; stipules 5–5.5 mm. long, obliquely lanceolate, acuminate, at first the margin ciliolate, later glabrate or nearly so, the sides and margins thin brown, membranous, the midrib heavy, cartilaginous and raised, densely appressed white pilosulous; petioles 6–10 mm. long, ascending white pilosulous; blades 20–65 mm. long, 9–32 mm. wide, oval or lance-oval, chartaceous, below appressed pilosulous on the veins and sparsely so on the intervals, above glabrous except for the minutely appressed pilosulous midrib, the apex subacute, the margin minutely low crenate or apiculate crenate; inflorescences axillary, appressed puberulent, 1-flowered, single; peduncle 3–6 mm. long; bracts 2 mm. long, ovate; pedicels 2–4 mm. long, ascending white pilosulous, near the middle bearing two subopposite bracts like the stipules but ovate, 2–3 mm. long; flowers divergent; sepals 4–5 mm. long, ovate-lanceolate, 1.5 mm. wide, the thickened, heavy midrib 0.5 mm. wide, it and the broad central strip densely appressed white pilosulous, the rest brown, membranous, glabrous but for the ciliolate margin; corolla irregular, the lower two thirds of the petals forming a claw, concave and channel-like, the limb expanded and reflexing in anthesis, white hirsutulous without; lower petal longer and larger than the others, spatulate, 14.5 mm. long (13 mm. when dried), the limb fleshy, 2.4 mm. wide, the claw 1.8 mm. wide, channeled, fleshy, with narrow membranous margins; lateral petals narrowly spatulate 13 mm. long (when boiled), the limb 0.9 mm. wide, sharply bent and reflexing, the claw 1.4 mm. wide, channeled and fleshy

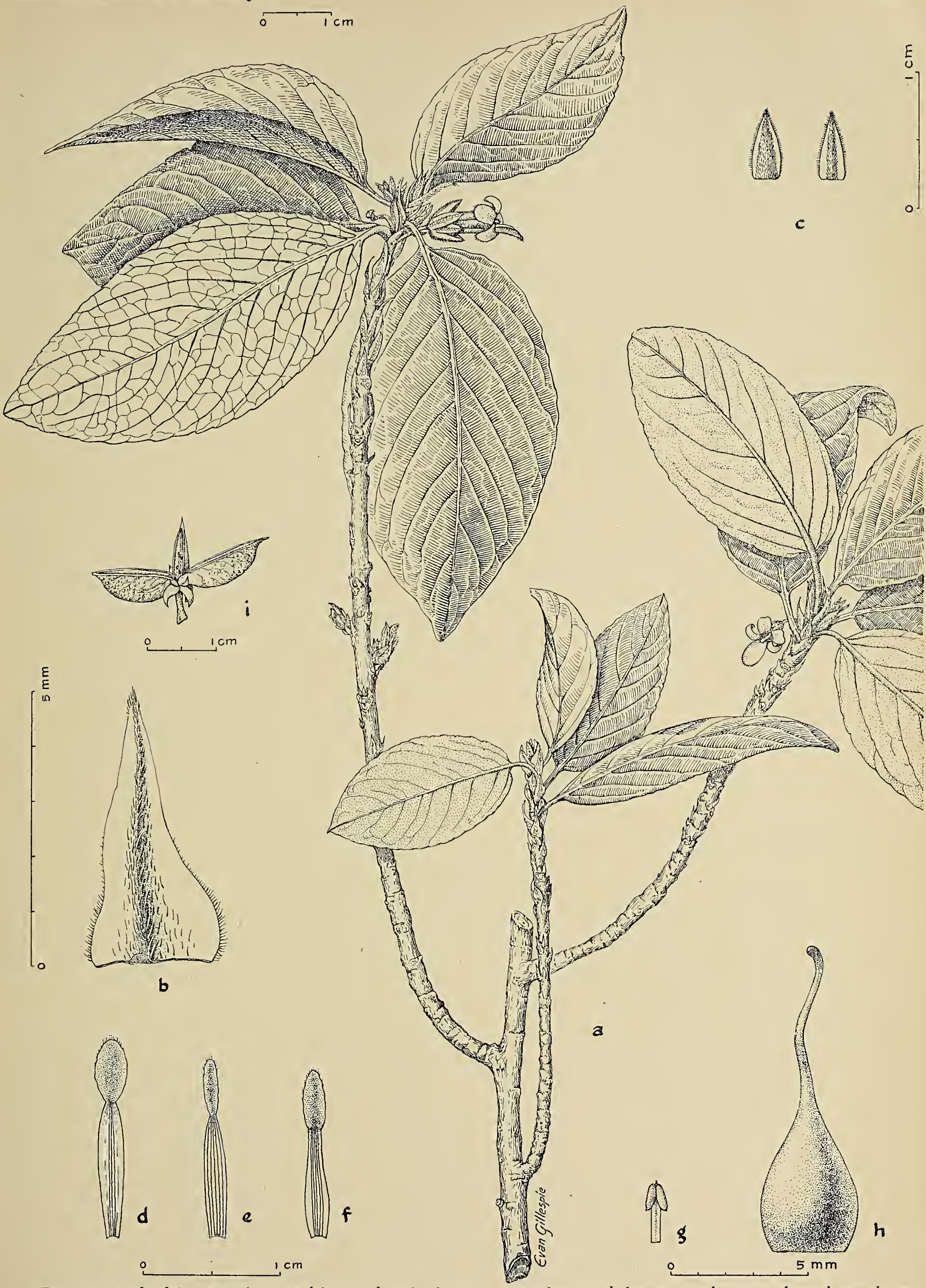


FIG. 12. *Isodendrion Remyi*. *a*, Habit×1; *b*, stipule×8; *c*, sepals×2; *d*, lower petal×2; *e*, lateral petal×2; *f*, upper petal×2; *g*, lower stamen×4; *h*, pistil×4; *i*, capsule×1. From the type, Nihau, Remy 534.

with narrow membranous margins; upper petals narrowly spatulate, 12.2 mm. long (when boiled), the thickened fleshy limb 4.2 mm. long, 1.7 mm. wide, the claw 1.8 mm. wide; filaments 1.3 mm. long, ligulate, anthers 1 mm. long, the oblong anther sacs divergent below, connivent at the apex on the two lateral stamens, lacking any appendage, on the upper and two lower stamens with a terminal bristle-like appendage 0.3 mm. long; ovary 6 mm. long, 2.8 mm. in diameter, ovoid, glabrous; style 5 mm. long, subulate, deflexing at the slightly larger, semiglobose stigma; capsule 12 mm. long, 7 mm. wide, brown, cartilaginous, reticulate, warty, splitting into 3 valves which are narrow trough-shaped but rounded at the back ridge; seeds not seen, 4 per valve.

TYPUS: Iles Sandwich, Nihau, spec. nova?, pyrifolio aff., foliis acuminatis flore xxx [illegible], 1851–1855, *J. Remy 534* (GH); also isotypes (L, P), (st. lf. fl. fr.).

Named in honor of Jules Rémy who collected plants in the Hawaiian Islands from 1851 to 1855.

13. **Isodendrion subsessilifolium** Heller, Minn. Bot. Stud. 1: 856–857, pl. LIV, 1897.

ILLUSTRATIONS: Figure 13; and Heller, Plate LIV.

DESCRIPTION OF TYPE: "A slender, wand-like shrub, two to six feet high, simple or sometimes sparingly branched, the branches ascending," plant glabrous; older bark brown to gray, smooth or longitudinally wrinkled, the stems 3–5 mm. in diameter, roughened by the persistent rigid stipules; leaf scars 2 mm. wide, depressed rounded shield-shaped, pale, with 3 bundle scars; leafy branchlets 2–3 mm. in diameter, leafy for 10–25 cm., the internodes 4–23 mm. long, hence the stipules remote; leaves alternate, spreading, numerous but not crowded; stipules 3.2–4 mm. long, obliquely narrow deltoid, with a broad thickened midrib, the membranous margin ciliolate; petioles 2–3 mm. long, stout; blades 3–10.5 cm. long, 12–44 mm. wide, oblong-oblanceolate to elliptic-oblanceolate, subcoriaceous, prominently netted reticulate veined above and below, above dark green, below tawny green, the margins shallowly undulate or obscurely serrulate; flowers axillary, single or several, the peduncle 2–3 mm. long, covered by stiff bracts similar to but smaller than the stipules; sepals 2.8–3.1 mm. long, 0.9 mm. broad, lanceolate, the back glabrous, prominently 3-nerved and dark in the center third, the rest pale and membranous, the margins puberulous ciliolate in the upper third; corolla irregular, glabrous, the lower two thirds of the petals forming a concave channel-like claw, imbricate laterally, enfolding the neighboring ones (but not spirally so, as shown in Heller's plate LIV) and imitating a corolla tube, the limb expanding and reflexing in anthesis; the lower petal longer and larger than the others, 13 mm. long (when boiled), the limb 4.7 mm. long, 2.8 mm. wide, elliptic oblong, thick and fleshy, almost flat, the apex retuse; claw 8.5 mm. long, 2.5 mm. wide, at base membranous and 5-nerved, towards the apex firmer and channeled; lateral petals 12 mm. long, narrowly spatulate, slightly contracted at apex of claw, membranous, especially below; limb 3.3 mm. long, 2 mm. wide, oval; claw 8.5 mm. long, 1.8 mm. wide, 3-nerved from the base; upper petals 11 mm. long, narrowly spatulate, membranous; the limb 3.2 mm. long, 2 mm. wide, oval; claw 7.8 mm. long, 3 mm. wide, membranous, 3-nerved; stamens subequal, filaments 1.7 mm. long, tapering upwards from the 0.4 mm. wide base; anthers 1.1 mm. long, 0.6 mm. wide, elliptic oblong, bearing at the apex an incurved bristle 0.1 mm. long; capsules 9–10 mm. long, ovate-lanceoloid in outline, deeply 3-lobed, beaked by the persistent style, greenish to brown, reticulate veined, the lobes 2-seeded, dehiscing to the base; seeds 2.1–2.3 mm. long, 1.7 mm. wide, shining, stramineous, the apex truncate, depressed.

TYPE: Kauai, Kaholuamanoa [=Kaholua-

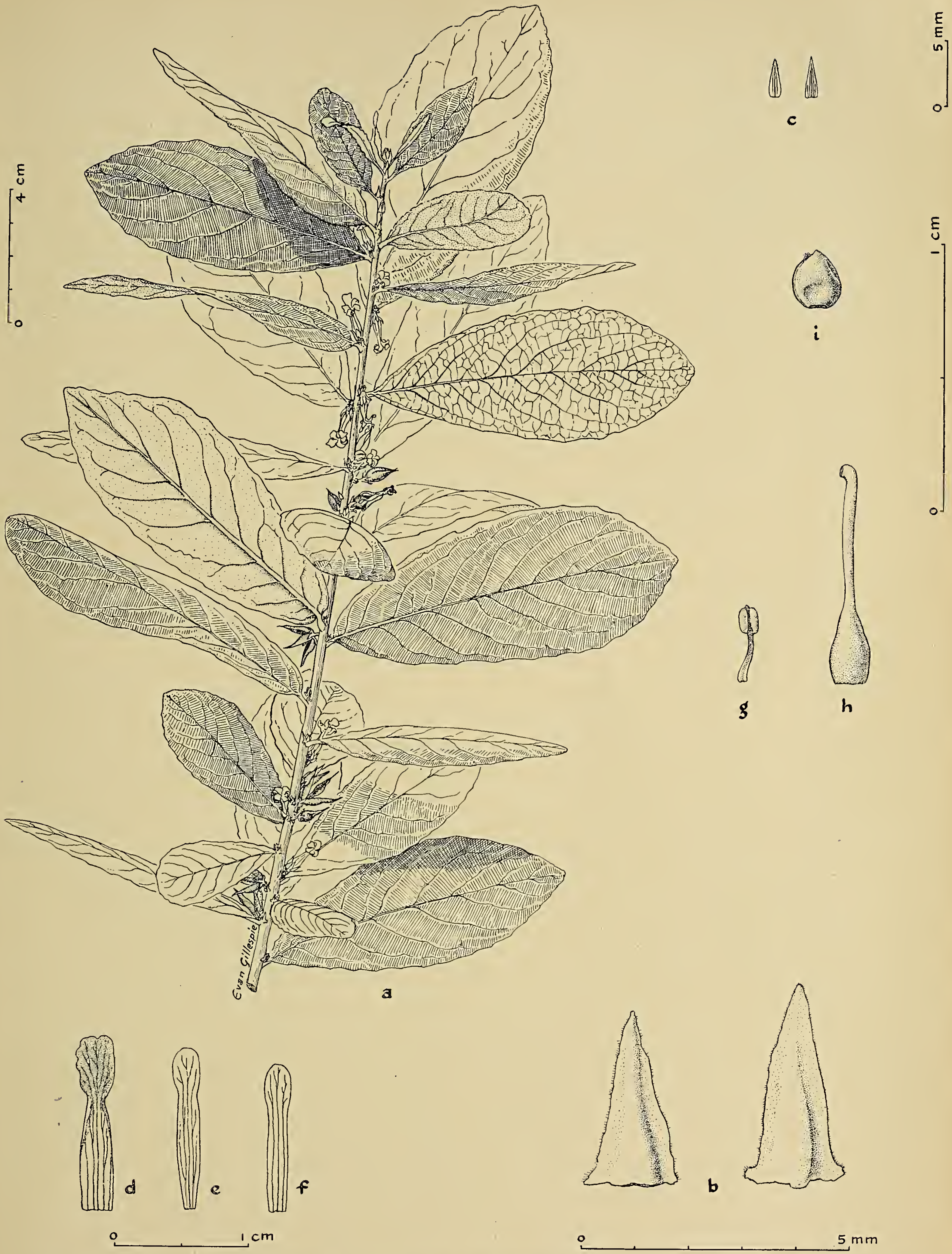


FIG. 13. *Isodendrion subsessilifolium. a*, Habit×½; *b*, stipules×8; *c*, sepals×2; *d*, lower petal×2; *e*, lateral petal×2; *f*, upper petal×2; *g*, stamen×4; *h*, pistil×4; *i*, seed×4. From isotype, Kaholuamanoa, Heller 2,828.

manu], above Waimea, Sept. 10–16, 1895, *A. A. Heller 2,828*. There were examined four isotypes at (BISH), (st. lf. fl. fr.); one at (US), (st. lf. fl.); one at (GH), (st. fl. lf. fr.); one at (E), (st. lf. fl.); and one at (L.), (st. lf. fr.). In his original account Heller added that it was growing at 2,000 feet in a ravine between the forks of the Waimea river.

Heller's excellent and abundant type collection included mature fruit, but he neither described nor figured that state of the plant.

SPECIMENS EXAMINED: Kauai, Olokele Canyon, shaded slope, only one plant seen, July 3, 1926, *O. Degener 17,348* (NY), (specimen sterile); (GH), (st. lf. fl. fr.).

The specific name was obviously formed from the Latin, *sub-*, somewhat so; *sessilis*, sitting close (or stalkless); *folium*, leaf, in allusion to its nearly stalkless leaves.

14. *Isodendrion waianaeense* sp. nov.

ILLUSTRATIONS: Figure 14.

DIAGNOSIS TYPI: Frutex 3 m. alta, ramis 3–4 mm. diametro divergentibus cortice brunneo vel griseo sublaevi, cicatricibus 2–2.3 mm. latis suborbiculari-scutelliformibus pallidis laevibus, fasciculis 3, ramulis foliferis 1–16 cm. longis 2–3 mm. diametro cum 4–18 foliis divergentibus non aggregatis, internodis 2–15 mm. plerumque 3–5 mm. longis, foliis alternis, stipulis 2.3–3.2 mm. longis oblique deltoideis carina incrassata dorso glabro marginibus ciliatis, petiolis 1–3 mm. longis validibus glabris, laminis 3.9–12.5 cm. longis 19–43 mm. latis glabris crassis firme chartaceis elliptico- vel oblongo-oblanceolatis supra olivaceis et prominente reticulatis infra pallide viridibus prominente reticulatis, floribus singulis axillaribus, pedunculis 0.2–1 mm. longis bracteatis, pedicellis 0.2–1 mm. longis glabris, sepalis 3.4–3.5 mm. longis 1.5 mm. latis lanceolatis vel anguste deltoideo-lanceolatis chartaceis 3-nervatis carina incrassata in regio mediale purpureo sed in sicco brunnescenti ad apicem marginibus membranaceis ciliolatis, petalis inaequalibus, petala inferiore 10.5 mm. longa (postquam bullanda), ungue 6.5 mm. longo 1.7 mm. lato ligulato sed in medio latiore membranaceo 5-nervoso ad apicem canaliculato opaquo purpureo sed in sicco bruneo, limbo 4 mm. longo 2.7 mm. lato ovali cucullato carnoso opaquo viridescenti, petalis lateralibus 10 mm. longis ligulatis ad basim et apicem angustioris 3-nervosis, limbis 3.5 mm. longis 1.7 mm. latis carnosis, petalis superioribus 9.5 mm. longis 1.5 mm. latis ligulatis 3-nervosis, limbis obtusis carnosis, staminibus aequalibus 5.2 mm. longis, filamentis ligulatis 1-nervosis, antheris 2.5 mm. longis ovatis sacis anguste ellipsoideis connectivo in apice plano extenso, ovario 3–11 mm. longo lanceoloideo, stylo 3.5–4 mm. longo filiforme, stigmate laterali orbiculari, capsulis 7 mm. longis lanceo-ovoideis valvis 1.5–1.8 mm. profundis extra viridescentis et purpureo-bruneo-striatis nervis vix evidentis, seminibus 3 mm. longis 2.1 mm. diametro late ovalibus obscure viridescentibus.

DESCRIPTION OF TYPE: Shrub; 3 m. tall, the first branch 1 m. from the ground, the crown open; older bark brown to gray, nearly smooth, these twigs 3–4 mm. in diameter, largely free of stipules; leaf scars 2–2.3 mm. wide, suborbiclar-shield-shaped, pale, smooth, with 3 bundle scars; leafy branchlets 2–3 mm. in diameter, leafy for 1–16 cm., the internodes 2–15 mm., commonly 3–5 mm. long; leaves alternate, spreading 4–18 in number, but not crowded; stipules 2.3–3.2 mm. long, obliquely deltoid, the back smooth and with thickened, heavy midrib, the margin ciliate; petioles 1–3 mm. long, stout, glabrous; blades 3.9–12.5 cm. long, 19–43 mm. wide, glabrous, thick, firm chartaceous, elliptic or oblong-oblanceolate, the margin irregularly low undulate, the upper surface olive green and prominently raised reticulate veined, the lower pale green and similarly veined; flowers axillary, single, the peduncle 0.2–1 mm. long, many bracted; pedicel 0.2–1 mm. long, glabrous; sepals 3.4–3.5 mm. long, 1.5 mm. wide, lanceolate to narrowly deltoid lanceolate, chartaceous, but near the obtuse

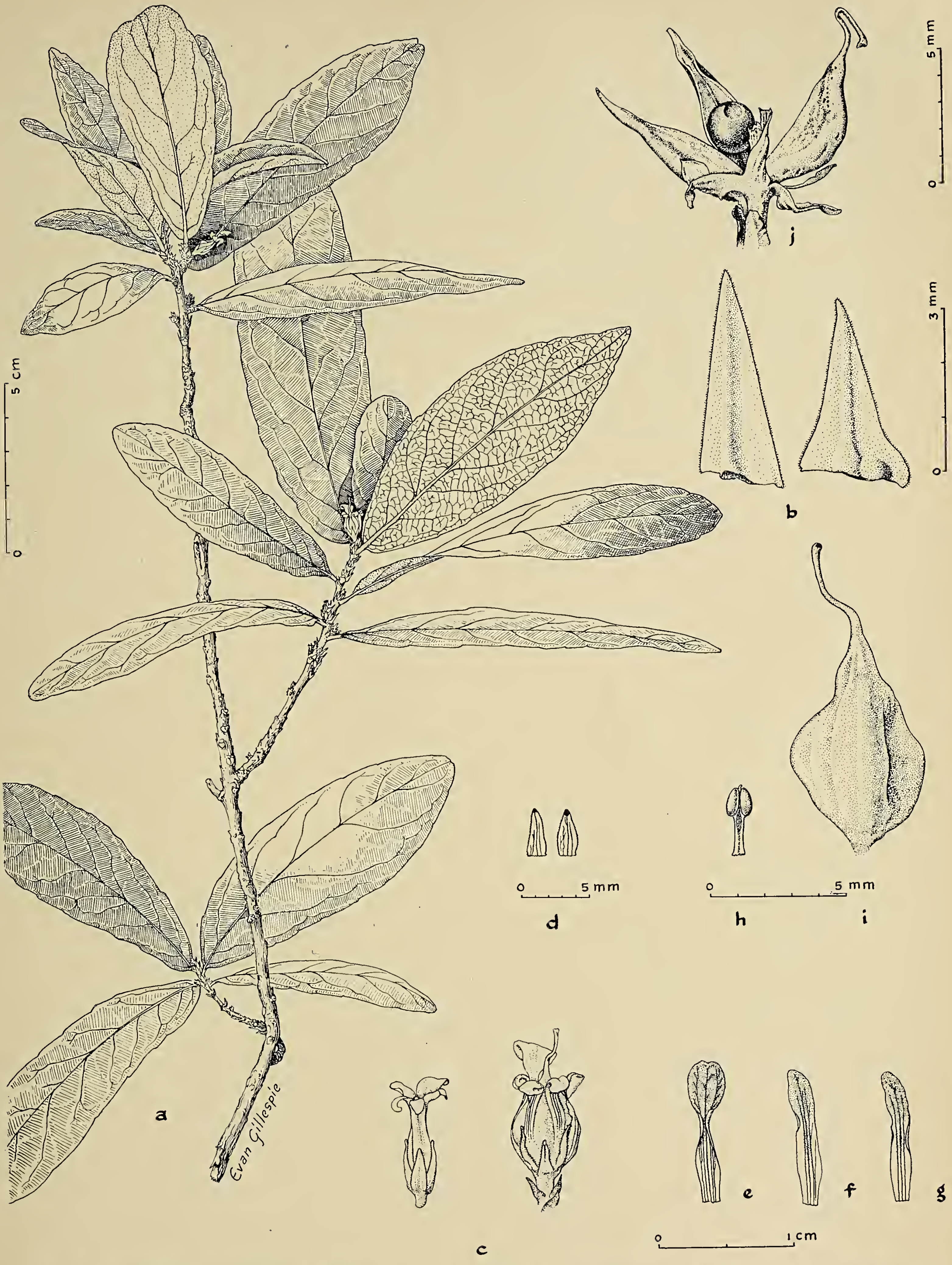


FIG. 14. *Isodendrion waianaeense. a,* Habit × ½; *b,* stipules × 8; *c,* flowers × 2; *d,* sepals × 2; *e,* lower petal × 2; *f,* lateral petal × 2; *g,* upper petal × 2; *h,* stamen × 4; *i,* pistil × 4; *j,* capsule × 4. From the type, Makaleha, Hatheway 398.

apex, the narrow membranous margins pale and ciliolate, the central strip distally "purple" but drying madder brown, 3-nerved from the base, the midnerve stronger, the laterals weak and soon forking; corolla irregular, the lower two thirds of the petal forming a channel-like claw, the limb expanding and reflexing in anthesis; lower petal the largest, 10.5 mm. long (when boiled), the claw 6.5 mm. long, 1.7 mm. wide, ligulate but slightly widened near the middle, membranous, 5-nerved from the base, but only the 3 central nerves strong, towards the throat the tissue thick, firm opaque and the shape channel-like, it and the other petals distally with a heavy central strip "purple," drying madder brown, the limb 4 mm. long, 2.7 mm. wide, oval, cucullate, fleshy, firm and opaque, greenish; lateral petals 10 mm. long, ligulate, slightly narrowed at base and at the throat, 3-nerved, the nerves nearly simple, the limb elliptic, 3.5 mm. long 1.7 mm. wide, thick, fleshy; upper petals 9.5 mm. long, 1.5 mm. wide, ligulate, the claw 3-nerved from the base, the limb obtuse, thick, fleshy; stamens equal, 5.2 mm. long; filaments ligulate, 1-nerved; anthers 2.5 mm. long, ovoid in outline, the anther sacs narrowly ellipsoid, the connective distally bearing a projecting flat membrane, incurved and homologous to the prickle of the other species; ovary 3–11 mm. long, lanceoloid; style 3.5–4 mm. long, filiform; stigma lateral, orbicular; capsule 7 mm. long, lance-ovoid, the wide-spreading valves 1.5–1.8 mm. deep, the surface greenish, streaked with madder-brown, the veins scarcely evident; the only seed seen 3 mm. long, broadly oval in outline, 2.1 mm. wide, dull greenish.

TYPUS: Oahu, Mokuleia, Waianae Range, West Branch of East Makaleha Stream, in side gulch, elev. 1,820 ft., dark dryland slope forest of *Diospyros ferrea* var. *sandwicensis*, *Ceodes*, *Planchonella*, etc., my quadrat No. 7, 9-ft. tree, first branch 3 ft. from ground, crown open, flrs. greenish purple, Oct. 4, 1950, *William H. Hatheway 398* (BISH), (st. lf. fl. fr.); isotypes sent to (F, NY, C. Skottsberg).

Superficially this species resembles *I. subsessilifolium* of Kauai, but there are several technical differences. It grows near the type

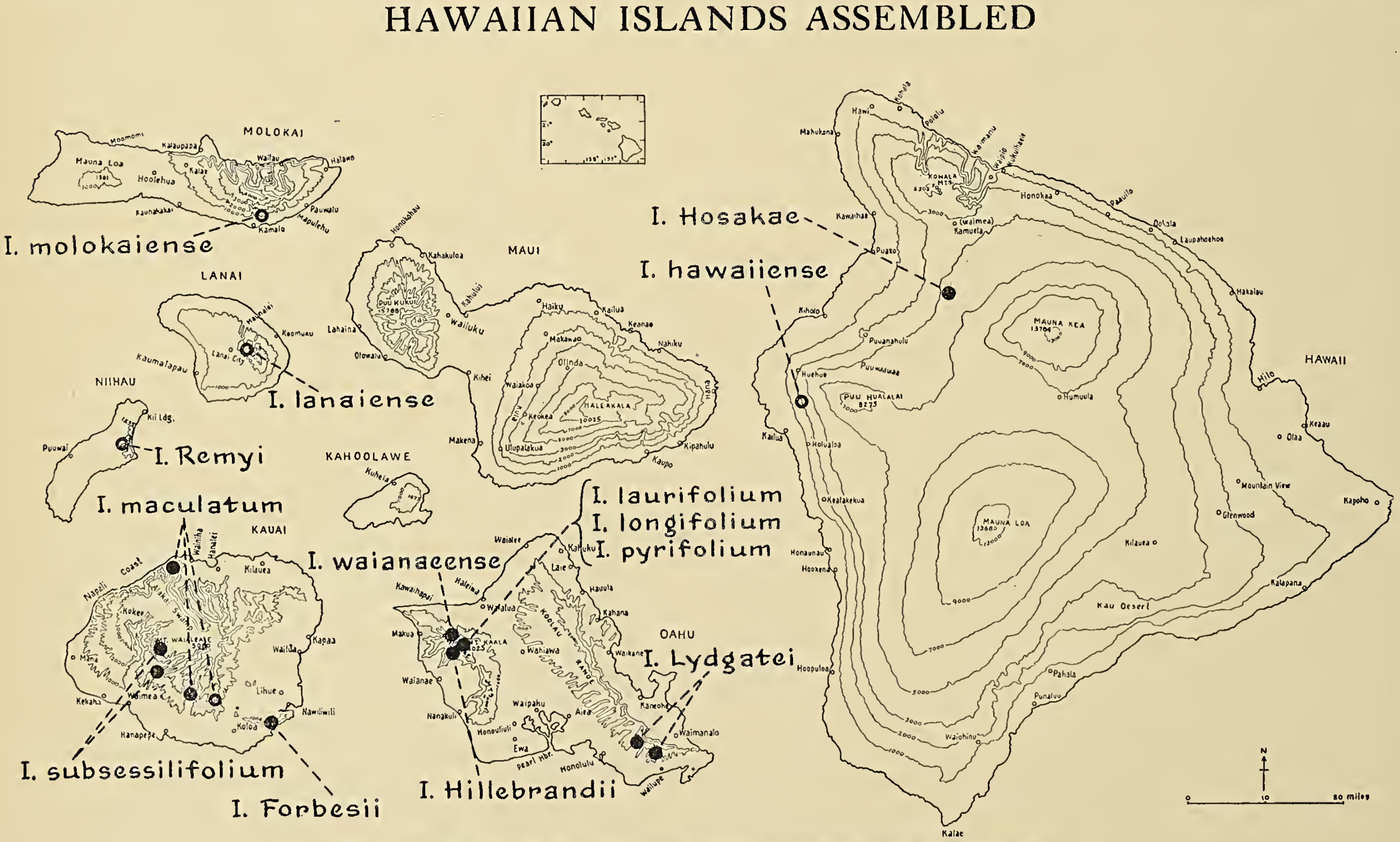


FIG. 15. Map of distribution of the species of *Isodendrion*.

localities of *I. pyrifolium*, *I. longifolium*, *I. laurifolium*, and *I. Hillebrandii*, but this new species is found in a different valley on the east, or windward, side of the Mt. Kaala massif. Its foliage suggests that of *I. laurifolium*, but the characters of stipules, sepals, petals, and anthers are quite different.

The specific name is made from the name of the Waianae Mountains, and the Latin place suffix, *-ensis*.

Excluded Species

Isodendron Fauriei Lévl., Fedde Repert. Spec. Novarum Regni Veg. 11: 63, 1912.

This binomial had the generic name misspelled; it should have read *Isodendrion*, the genus of Violaceae intended by Léveillé. His labels on the two isotypes in the Bishop Museum also have "*Isodendron*" in his handwriting. His 3-line diagnosis, brief, as was his custom, gave few characters. This diagnosis was worded so as to state the contrasting differences from "*I. pirifolio*" [=*I. pyrifolium* Gray]. It is certainly distinct from that, but so, too, is any alleged new species distinct if placed in the wrong family. Rock purchased a set of these Faurie collections from Léveillé (the ones now in the Bishop Museum), then published a critical review of Léveillé's work. He reduced *I. Fauriei* Lévl. to *I. pyrifolium* Gray. The two isotypes examined agree with the original description and positively are flowering specimens, from Molokai, of *Gouania Hillebrandii* Oliver in Hillebrand, Flora of the Hawaiian Islands 83, 1888, a member of the Rhamnaceae. This latter species was described from Maui, but now is known to occur also on Lanai and Molokai.

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Spawning Behavior of the Cottid Fish *Clinocottus recalvus* (Greeley)

ROBERT W. MORRIS[1]

CLINOCOTTUS RECALVUS (Greeley) 1899 is a small tide-pool cottid found along the coast of California and Lower California. This paper reports briefly on the spawning activities of individuals confined in a laboratory aquarium. Dr. Rolf L. Bolin has kindly furnished information concerning the anatomy and biology of this and related species.

Two females and one male were collected from tide pools at Pacific Grove, California, on February 5, 1951. They were placed in an aquarium, which had wooden ends and bottom and glass sides and was supplied with running water. They were fed regularly on chopped sea mussels. A decided preference was shown for the mussel gonads; the mantle edges were somewhat less acceptable, and the gills were seldom eaten.

The aquarium contained two small granite rocks. It was intended that these would provide a suitable place for the deposition of eggs. Grooves, about 0.5 cm. wide and 1.5 cm. deep, routed along the bottom and ends of the aquarium and in which the glass sides were set, also provided places for the deposition of eggs.

Periodic examination of the aquarium disclosed the deposition of egg clusters on or about the following dates: February 27, March 3, 17, 19, 23, and 27, April 9 and 21, and May 6, 1951. Each of the clusters was removed shortly after its discovery, as I soon learned that prolonged contact with the wood of the tank resulted in the death of the embryos.

Of the nine clusters of eggs deposited, five were laid in the vertical grooves of the ends of the aquarium, two were laid beneath one of the stones, one was laid in the vertical crack between the two stones, and one was laid in one of the grooves of the bottom. Each of the clusters fitted closely the place where it was deposited, indicating that they were laid in a very fluid state.

The first five clusters were of a deep vinaceous color. The sixth was of the same color, but of lesser intensity. The last three clusters were bright orange, very closely matching the color of the mussel gonads upon which the adults had fed.

Prior to the deposition of each of the last four clusters of eggs, the female concerned showed a marked ventrally directed protrusion around the anus (Fig. 1*a*). The profile of the bulge became progressively more acute up to the time the eggs were spawned. This was not observed preceding the earlier spawnings, but could have been overlooked.

It was not possible to determine which female produced the first four egg clusters, since no differences in appearance were noted. However, it was possible to determine which female deposited each of the last five clusters, since their abdominal regions were quite collapsed immediately following spawning. The two females spawned alternately over the period March 23 to May 6.

On three occasions spawning took place

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[1] Hopkins Marine Station, Pacific Grove, California. Manuscript received January 29, 1952.

during daylight hours, at about 8:00 A.M., 2:00 P.M., and 5:00 P.M. The time at which the other spawnings occurred is not known.

Copulation was observed on two occasions. A different female was involved each time. The behavior pattern was almost identical in both cases.

One of the females deposited a cluster of eggs at about 2:00 P.M. on March 23. These eggs were spawned in a groove at one end of the tank, against the glass of the side and about 6 inches above the bottom. Immediately after spawning, the female dropped down to the bottom of the tank. At this time, the male came alongside the female and seized the female by the left pectoral fin as shown in Figure 1*b*. It appeared that the male was trying to induce the female to return to the site of the egg cluster. The male persisted in dragging the female across the aquarium by the pectoral fin. After this struggle had gone on for perhaps 5 minutes, the female did return to a position over the egg cluster, clinging to the side and end of the tank, with head uppermost. The male then moved up against the left side of the female and held this position for only a moment and then turned and passed over the back of the female, as in Figure 1*c*. This was repeated several times, the female being rolled slightly to the right side on each occasion. On about the sixth such attempt, copulation was achieved while the male was across the female at right angles (Fig. 1*d*). The vigor of the male's thrust, which lasted for perhaps 3 seconds, carried the two away from their position and into midwater. Immediately thereafter, the male dropped to the bottom of the tank and the female returned to the previous position over the egg cluster. The female clung there for about 5 minutes, during which time a large quantity of milt poured from the region of the genital opening and created a dense cloud in the immediate vicinity. After that, the female too dropped down to the bottom of the aquarium.

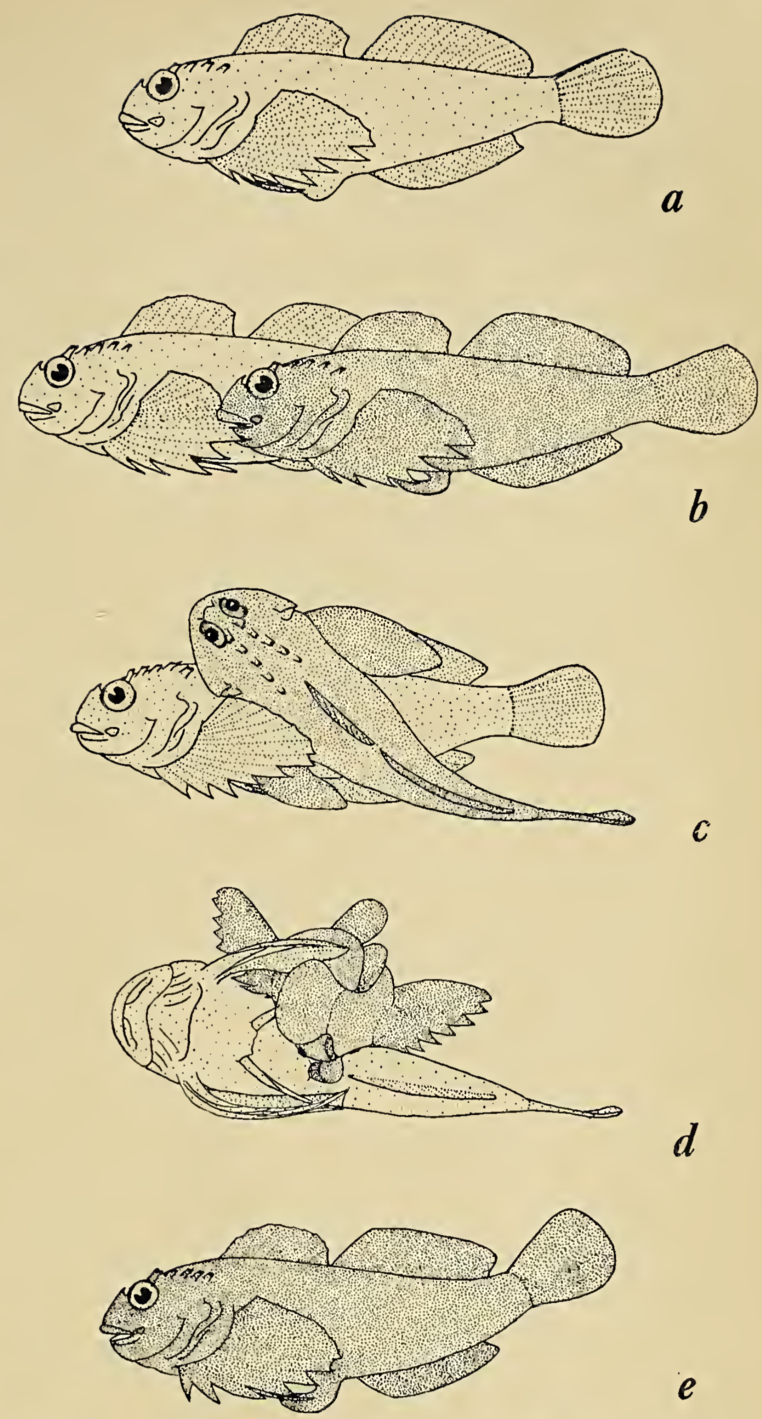

FIG. 1. *Clinocottus recalvus*. *a*, Female with abdominal protrusion, indicating readiness to spawn; *b*, position at the start of mating activities (the male in this and subsequent figures is represented by the darkly stippled individual); *c*, the male moving over the body of the female; *d*, position at copulation; *e*, position of the male after copulation.

Copulation with the second female occurred shortly after deposition of an egg cluster at about 8:00 A.M. on March 27. The behavior of the male and female was almost identical with that previously observed. This cluster of eggs was deposited in a vertical crack between the two stones. These stones gave a much better substrate to which the fish could cling. In consequence, they were not swept from the site during the copulatory thrust, but remained in a fixed position. After copulation the male dropped to the bottom, but did not lie there quietly as before. Instead, the tail was arched high away from the substrate and the mouth held open (Fig. 1*e*). Convulsive movements persisted for about 10 minutes, subsiding gradually.

On April 5, the male was removed from the aquarium. The female which had spawned and copulated on March 23, spawned again on April 9 and again on May 6. Both clusters deposited after removal of the male proved fertile and developed normally. The female that had spawned and copulated on March 27, spawned again on April 21. Only about one half of the eggs of the spawning of April 21 developed. The remainder appeared to be infertile. The subsequent history of the eggs and the development of the larvae have already been described (Morris, 1951).

The two females measured 85 and 98 mm. in total length. During the period of February 27 to May 6, it is estimated that the total number of eggs laid by both was between 8,000 and 9,000. This estimate is based on the sizes of the clusters and on a count previously made on an egg cluster of the same species.

CONCLUSIONS

On both occasions of observed copulation, spawning preceded copulation by several minutes. The females continued to lay fertile eggs for several weeks after copulation. These two characteristics are reminiscent of the breeding behavior of some of the ovoviviparous fresh-water aquarium fishes.

The sharp difference observed in egg color suggests that this character is dictated by environmental conditions and possibly to a great extent by the nature of the food.

The fecundity of this species and the ease with which it is kept in aquaria indicates that it would be a very convenient subject for laboratory studies.

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Dew as a Source of Plant Moisture

LUNA B. LEOPOLD[1]

RECORDS OF THE FREQUENCY of occurrence or of the total amounts of dew are scarce. This is surprising in view of the fact that dew has been used for water supply in certain Mediterranean countries for many centuries. The lack of records can undoubtedly be attributed to the difficulty of making quantitative measurements.

Dew is the moisture which condenses from the atmosphere on plants, soil, or other surfaces near the ground. Common experience tells us that dew forms primarily during the early morning hours when the temperature approaches its minimum diurnal value. It often forms in the early evening also, and in such cases probably continues to accumulate slowly throughout the night. However, the rate of formation must decrease owing to the fact that the layer of air closest to the ground becomes saturated. The vapor pressure gradient at the immediate surface of ground becomes nearly zero and probably stays near zero because of lack of mixing in the lowest layers.

Temperature in a standard instrument shelter may give little clue to the probability of dew formation at the ground surface. The temperature gradient increases so rapidly in the lowest few feet near the ground that temperature at grass level is considerably lower than at the height of the instrument shelter. Radiational cooling is, of course, the cause of the low temperatures at ground level. It follows that dew will be heaviest on surfaces which are the best radiators, that is, dark and opaque surfaces such as green grass. For the same reason, dew will be heaviest when the wind is light or absent because the lack of mixing allows the temperature inversion near the ground to be maintained and to intensify.

Only plants which are shallow rooted could make use of dew because the moisture penetrates only a thin layer of soil and evaporates quickly when the sun begins to warm the surface. Pineapple is an example of a plant whose trough-shaped leaves allow dew to run down to the plant base. This tends to concentrate the dew water near the roots, which, being shallow, can utilize the dew with some efficiency. Dr. Gordon Nightingale measured with a pipette appreciable amounts of dew water which collected at the axil of pineapple leaves (personal communication). I have frequently observed the ground at the base of the pineapple stem to be noticeably moist as a result of dew collected by the leaves. The shade cast on the plant base by the leaf mass enhances the probability of intake by roots inasmuch as the shade reduces the evaporation rate.

My own experience in the semiarid southwestern United States supports the view that dew is sufficiently frequent to constitute, in all probability, an important source of moisture for some plants. Measurements of the frequency of dew in Hawaii tend to confirm this conjecture. Because data on dew frequency are uncommon, the record of measurement made during 2 years in Honolulu is of some interest.

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[1] 7305 Gloster Road, Washington 16, D. C. Manuscript received December 18, 1951.

The record was made in Kahala, a section of the city of Honolulu just east of Diamond Head, where the mean annual rainfall is approximately 20 inches. Every morning about 7 o'clock I walked across the lawn to read the rain gauge and at that time observed the relative amount of dew which collected on my shoes. The procedure has more an air of levity than of science but such a record is better than none. It was observed that this daily procedure provided enough experience to allow a consistent estimate of the relative amount of dew. The amount was recorded as one of four categories—none, light, moderate, or heavy. On days of rain, no record of dew was made because one could not tell whether the moisture was derived from dew or from precipitation.

Deducting from each month the number of days of rain or no record, the frequency of dew can be expressed as percentage of days. This represents, in other words, the percentage of possible days on which dew could occur in the absence of rain. The number of days, by months, is presented in Table 1. The annual march of dew occurrence is shown graphically in Figure 1.

TABLE 1

Frequency of Occurrence of Dew at Honolulu during the Period of October, 1947, to July, 1949

MONTH	TOTAL DAYS ON WHICH DEW WAS OBSERVED	TOTAL DAYS OF NO RAIN	PERCENTAGE RAINLESS DAYS
January.......	23	35	66
February......	27	45	60
March........	16	45	35
April.........	12	42	29
May..........	19	52	37
June.........	12	45	27
July..........	2	15	13
August.......	13	52	25
September....	15	53	28
October......	25	48	52
November....	27	43	64
December.....	7	23	30
Total......	198	498	40

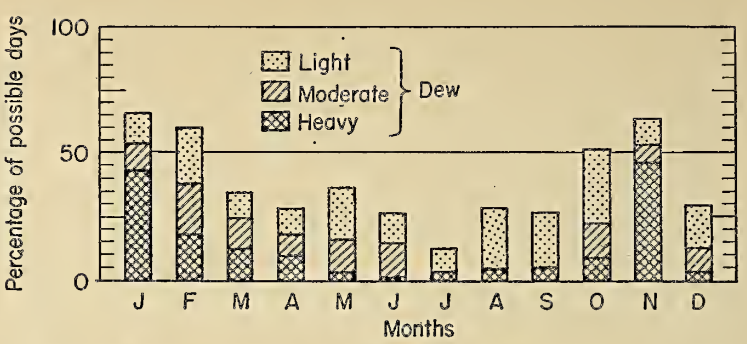

Fig. 1. Frequency of dew at Honolulu (as percentage of rainless days).

Despite the rough manner of collecting the data, the relatively smooth annual march lends credence to the record. The December percentage is low. This can probably be attributed to the fact that one of the two Decembers of record was relatively windy as indicated by a concurrent anemometer record. For July only one-half month of record is available.

Dew occurred on 198 days, which represented 40 per cent of the total rainless days. At the same place and in the same period, there were 217 days of some rain. Traces of rain were not counted as rain days. Of the 217 rain days, only 89 had amounts greater than 0.1 inch.

On many days of heavy dew, enough collected on the funnel of the rain gauge to drip into the collection tube where it could be measured as .01 inch. Assuming that the average amount of dew was .0075 inch in a day, which is indeed a guess but probably of the right magnitude, the dew contributed 0.8 inch per year. Let us compare this with the moisture contributed by light rains or showers. The total rain contribution of those days on which .01 to .09 inch of rain occurred was 2.6 inches per year. Of the total annual rainfall, the dew moisture would constitute about 4 per cent, while rain in the category .01–.09 inch in a day would constitute 13 per cent of the total.

The frequency of dew at Honolulu is greatest in winter and least in summer. Mixing ratio (grams of water vapor per gram of dry air) has a small annual variation with a maximum in late summer. The seasonal variation of temperature is also small. The mean temperature at Honolulu varies from about 71°F. in February to 78° in August (Palmer, 1950). The modest decrease of temperature during the winter months overcompensates for the winter minimum of moisture and enhances the possibility of reaching the dew point by radiational cooling at the ground surface. The annual march of dew frequency thus appears directly related to the annual march of minimum daily temperature.

The importance of dew lies not in the total quantity but in the frequency of occurrence. At the Kahala station there were nearly as many days of dew as days of rain. Because of the frequent showers in the trade-wind belt, the number of days of rain is unusually high relative to the annual rainfall.

Recent work has shown that radiational cooling of the ground surface causes moisture to condense within the pore spaces of the surface layer of soil. This moisture condenses out of the air which is in the soil pores. It has been demonstrated that this moisture is sufficient to affect soil moisture of road subgrades (Winterkorn, 1944), and it is possible that the same process also can provide water to plants.

Consider these facts in relation to the grasslands of the world. Grass or desert shrub characterizes a very large geographic area where the annual rainfall is roughly between 6 and 14 inches. Such areas are, by their meteorologic setting, characterized by a large number of days of no rainfall, and most of the annual rainfall occurs in relatively few days. It is reasonable to suppose, then, that in such an ecologic setting any factor which doubles the frequency of moisture availability, even though the moisture amounts be small, must materially affect the growing conditions of plants. It is suggested, therefore, that the occurrence of dew is a factor of some importance in sustaining the plant associations in grasslands and some xerophytic habitats.

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Redescription of *Aedes (Ochlerotatus) camposanus* Dyar (1918) as a Valid Species Found in the Coastal Plain of Ecuador

ROBERTO LEVI-CASTILLO[1]

DURING THE RAINY SEASON of 1950–51 the author collected a great deal of mosquito material near Guayaquil. Among the specimens taken from light traps were the male specimens of a species apparently unknown in the fauna of Ecuador. The specimens were sent to the United States National Museum in Washington and were determined as *Aedes* (*Ochlerotatus*) *eupoclamus* Dyar and Knab, 1906.

The author became doubtful of this identification as the male terminalia would not comply with the known descriptions of *A. eupoclamus* and asked for a slide specimen of this species from its type locality, Costa Rica. By courtesy of Dr. Alan Stone, a slide was obtained from the collection of the U. S. National Museum, and it was possible to make a comparison, which showed that, although the Ecuadorian specimens could be easily confused with *A. eupoclamus*, the claspettes, tenth sternites, and mesosomae were different. The Ecuadorian specimens proved to be a species described by H. G. Dyar (1918: 128) from specimens collected in Guayaquil. The types, male and female, are listed under No. 21916 in the U. S. National Museum collection, with the original name of *Aedes* (*Ochlerotatus*) *camposanus* Dyar. This species is very similar to *A.* (*O.*) *scapularis* Rondani and to *A.* (*O.*) *eupoclamus* Dyar and Knab, but it does not show a small retrorse filament in the claspette.

This species was named in honor of Professor Francisco Campos Rivadeneira, of Guayaquil, Ecuador, who submitted the specimens to Dyar in 1918.

Aedes (Ochlerotatus) camposanus Dyar, 1918

FEMALE: Proboscis dark with white spots. Palpi small, dark, with small silvery white spots. Occiput with dark integument and white erect scales; borders of eyes with same erect white scales and a few dark setae. Vertex with silvery white scales and a few dark setae, which form a tuft overhanging the clypeus. Neck with silvery white elongate scales. Prothoracic lobes showing tufts of silvery white scales and setae, with the integument olive-colored with freckle-like silver spots. Mesonotum showing a wide gray band in the middle, extending from pronotum to prescutellum, divided in the middle by a dark line and limited laterally by 2 black lines ending at the prescutellum with a tuft of white scales. Pronotum with tufts of white and light brown scales on each side and to center. Disc revetted with light brown and white scales and silvery setae. Prescutellum showing a large gray spot which becomes larger toward the scutellum, formed by white scales and silvery setae. Scutellum showing 3 lobes, the 2 lateral ones light brown with dark setae, the middle one with silvery white scales and setae; 2 dark spots in intersection of lobes. Pleurae and coxae revetted with small tufts of silvery white scales and setae with light brown integument with freckle-like silver spots. Coxae showing small silvery white tufts in

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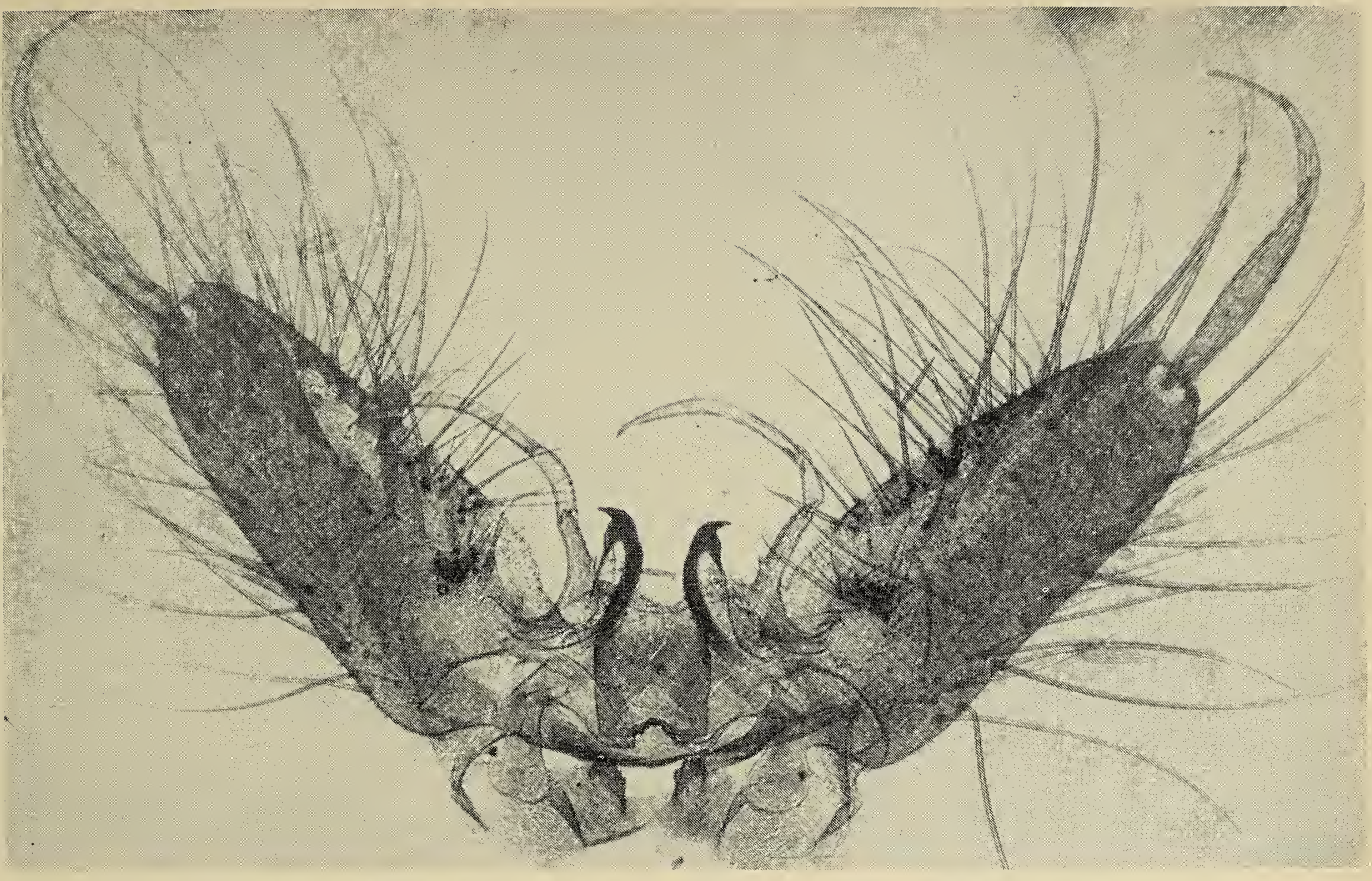

FIG. 1. Hypopygium of *Aedes* (*Ochlerotatus*) *camposanus* Dyar, 1918.

union with legs. Wings dark colored with dark scales. Femora of fore legs white with dark line in ventral surface. Tibiae dark with many white spots. First tarsi dark with white rings and spots. Second, third, and fourth fore tarsi dark with white spots; fifth fore tarsi dark, with white tip. Femora and tibiae of midlegs white with black spots; first tarsi dark with white spots; second and third tarsi with intermixed black and white scales; fourth and fifth tarsi dark scaled. Femora and tibiae of hind legs covered with white scales speckled by black scales. First tarsi white with black rings and spots; second tarsi black with freckle-like white spots, and 2 larger white spots, one basal, the other apical; third tarsi black with freckle-like white spots, with large terminal white spot; fourth tarsi black; fifth tarsi black with apical white spot. Last 6 abdominal segments show dorsally, in portion nearer thorax, revetment of silvery white scales, especially in basal and lateral portion of segments, forming characteristic silvery white banding that limits the segments and covers them laterally and ventrally. Venter totally covered with silvery white scales, lateral portions bordered by silvery white setae that seem hair-like, a characteristic of this species which does not show in *A.* (*O.*) *eupoclamus* Dyar and Knab.

MALE: Same color as female. Long palpi black with spots of silvery white scales and black setae. *Terminalia:* Coxite long, tapering, conical, longer than wide, with long hair-like setae and a few long oval scales in outer surface. Apical lobe round, small, with small setae. Basal lobe with strong setae, one of them prominent, sclerotized, with round sharp tip. Clasper strongly sclerotized basally, thickened toward the mid-portion then thinner subapically, curving apically, with sclerotized round base for a tapering, long, sclerotized apical filament. Claspette with sclerotized stem which becomes suddenly thinner in the middle, then thickened again toward the apex, where there is a sclerotization with a sickle-like filament becoming wider in the middle. The stem having many micropilae and very minute setae. Mesosome a sclerotized, truncated cone, tip slightly rounded, subbasally with some long filamentous setae, which are characteristic for this species. Tenth sternites elongate and partially sclerotized, showing a beak-like process in distal margin, very strongly sclerotized; some minute filaments arising from prominences on inner portion. Ninth tergites sclerotized, forming 2 lobes with 5 long sclerotized filaments at the tip and 1 in the middle.

TYPE LOCALITY: Guayaquil, Ecuador, as given by Dyar in his original description, this being the same locality where specimens which I have studied were collected. The species has been confused by many authors under the name *A. eupoclamus* Dyar and Knab, but has many characters that are unlike those of this Costa Rican and Central American species. I believe, therefore, that it should be placed as a valid species, not as a synonym of *eupoclamus*. In my opinion, *A.* (*O.*) *eupoclamus* has never existed in Ecuador or any other country of the Pacific coast of South America.

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News Notes

The Ninth Session of the South Pacific Commission was held from April 28 to May 7 at Commission headquarters in Noumea, New Caledonia. Delegates attended from the member governments of Australia, France, the Netherlands, New Zealand, the United Kingdom, and the United States of America. The session was under the chairmanship of the Senior Commissioner for the Netherlands, N. A. J. de Voogd.

At the Ninth Session it was agreed unanimously to extend the activities of the Commission to embrace Guam and the Trust Territory of the Pacific Islands under United States administration. This action follows the signing of an agreement by member governments at Noumea on November 7, 1951, including both territories within the scope of the South Pacific Commission.

Commission projects which the administrations of both territories have indicated are of special interest in relation to their own problems and activities include, in the field of public health, those dealing with filariasis and elephantiasis, tuberculosis, and child nutrition; in the economic field, the development of cash crops, the control of pests, diseases and weeds, the introduction and distribution of economic plants, the development of fisheries, and the improvement of tropical pasture and stock; and, in the field of social development, the vocational training of island peoples, the use of visual aids in child and adult education, mass literacy, and community development.

During the Ninth Session the Commission reviewed arrangements for the holding of the Second South Pacific Conference at its headquarters in April of next year.

Over seventy delegates are expected to attend next year's Conference from 18 territories, as well as from the Kingdom of Tonga, to discuss problems relating to the welfare and progress of their peoples. It is anticipated that observers from certain missionary bodies and scientific organizations active in the South Pacific will be present.

A National Science Foundation grant of $19,000 has been received by D. Elmo Hardy, Department of Zoology and Entomology, University of Hawaii, and entomologist with the Hawaii Agricultural Experiment Station. The grant will cover three years' work on the first complete classification of the Diptera of Hawaii. The resulting volumes will be incorporated in Elwood C. Zimmerman's series on *Insects of Hawaii*, published by the University of Hawaii Press in co-operation with the Hawaii Sugar Planters' Association. Dr. Hardy will spend his third year of work in Berlin, Paris, and London, as all early specimens of Diptera from Hawaii were taken to Europe. A. Smith, scientific artist at the British Museum, will do the illustrations.

Local scientists enjoyed the privilege of conferring with scientist members of the Danish Deep-sea Expedition aboard the frigate "Galathea," which stopped in Honolulu March 25–28. The leader of the expedition, Dr. Anton F. Bruun, addressed an open meeting of the Society of Sigma Xi on some aspects of deep-sea research.

Book Notice

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——— 1920*b*. Cerotrioza (Psyllidae, Homoptera). *Hawaii. Ent. Soc., Proc.* 4 (2): 374–375.

ROCK, JOSEPH F. 1916. The sandalwoods of Hawaii; a revision of the Hawaiian species of the genus *Santalum. Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry Bot. Bul.* 3: 1–43, 13 pls.

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VOL. VI OCTOBER, 1952 NO. 4

PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL
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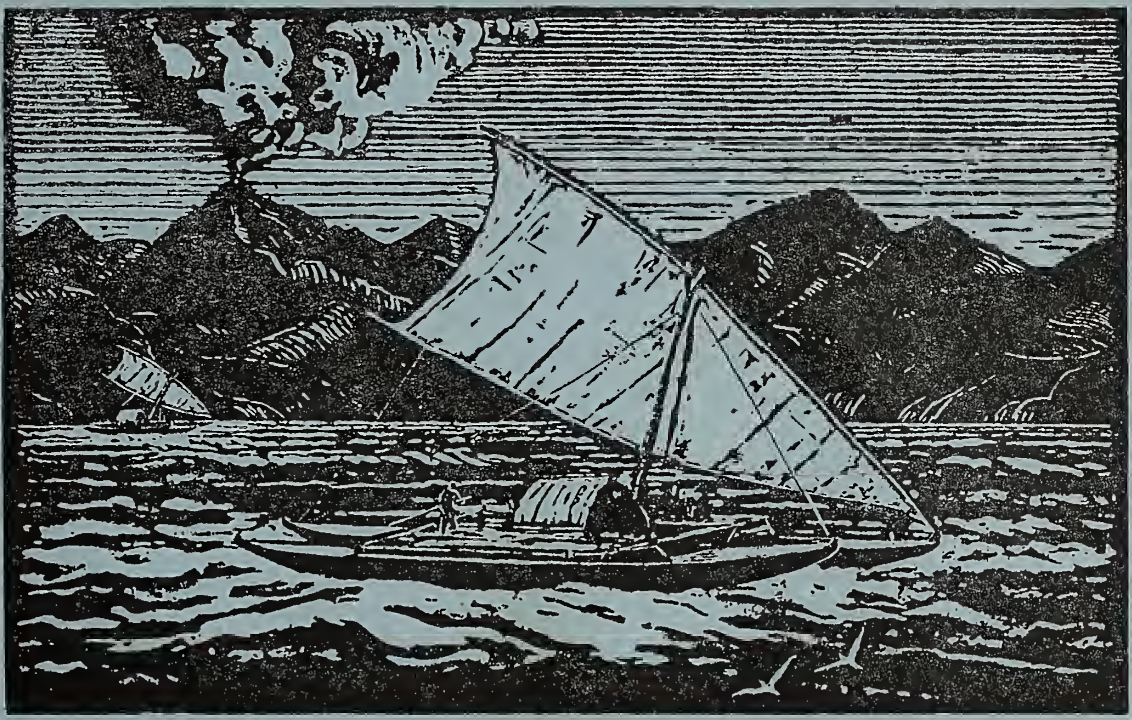

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The Kona Earthquake of August 21, 1951, and Its Aftershocks[1]

GORDON A. MACDONALD and CHESTER K. WENTWORTH[2]

INTRODUCTION

AT THREE MINUTES before one o'clock on the morning of August 21, 1951, the southwestern part of the island of Hawaii was shaken by the strongest earthquake recorded there since 1868. The earthquake of August 21 was felt strongly all over the island of Hawaii, weakly on the island of Maui, and in Honolulu, 180 miles away from its origin. Extensive damage resulted in the central Kona district, and lesser damage extended all the way to Naalehu, about 38 miles from the epicenter. The major earthquake was followed by a large number of aftershocks which, although they did little damage, kept the populace of Kona uneasy for several weeks.

A detailed study of the earthquake was immediately undertaken by the staff of the Hawaiian Volcano Observatory. No sharp division of labors existed, but for the most part Macdonald was responsible for the general and instrumental phases of the investigation and Wentworth for the detailed studies of damage, such as that affecting water tanks, stone walls, and gravestones.

Acknowledgements: It is impossible to mention by name all the persons who aided the investigation by contributing observations on the earthquake itself and data on resulting damage. To all these we extend our sincere thanks. Special thanks are due Howard M. Tatsuno, seismograph operator at Konawaena High School near the epicentral area; Sister Mary Thecla, seismograph operator at St. Joseph's School in Hilo; Mrs. Alfred E. Hansen at Naalehu, Allan P. Johnston of Kapapala, and Nancy R. Wallace of Kealakekua, who contributed descriptive reports of many of the aftershocks. Roland E. White, of the Honolulu Magnetic Observatory, U. S. Coast and Geodetic Survey, kindly sent copies of the seismograms of the major earthquake as recorded at Barbers Point, on Oahu. Commander C. A. George, of the Coast and Geodetic Survey, supplied copies of the tide gauge records from Honolulu and Hilo harbors, showing the small tsunami that followed the earthquake. Many persons supplied information on damaged water tanks. Among these Mark Sutherland, Principal of Konawaena School, John Iwane, Extension Service, University of Hawaii, and Masuoka Nagai, of Captain Cook Coffee Company, were especially helpful.

NARRATIVE

Most residents of the island of Hawaii were in bed when the earthquake struck. Nearly everyone in the Kona and Kau districts was awakened, and most people rushed outdoors. Persons in the area near the epicenter reported that the initial movement was largely up and down, with some swaying in an east-west direction, increasing in intensity and giving way to what appeared to be a vortical motion. Noise during the earthquake was intense as doors and windows rattled, dishes and furniture toppled to the floor, water tanks collapsed, and rocks rolled down from stone walls and banks. A few persons who were awake at the time the earthquake occurred reported that the quake was immediately preceded by a dull roar seeming to come from the ground. Shaking is reported to have been nearly continuous for an hour or more after the major shock.

---

[1] Publication authorized by the Director, U. S. Geological Survey. Manuscript received May 7, 1952.

[2] Director and Geologist, respectively, Hawaiian Volcano Observatory, Hawaii National Park, Hawaii.

Macdonald was driving through Naalehu, 36 miles from the epicenter, when the earthquake occurred. The car swerved violently, as though it had struck a mudhole. Immediately afterward branches started to snap from trees overhead and fall on the pavement.

Within a matter of moments several houses, churches, and a school building were badly damaged, many other houses slightly damaged, about 200 water tanks destroyed, many miles of stone wall thrown down, roads partly blocked by rock slides, road pavement and shoulders badly cracked, cemeteries damaged, telephone communication and electric power supplies disrupted. Fortunately, only two persons were injured, and they not seriously.

Damage extended for more than 50 miles along the highway that encircles the island, from Holualoa on the north to Honuapo on the southeast. Damage was greatest along the 10-mile stretch from the village of Captain Cook to Hookena (Fig. 1), but as far away as Naalehu many dishes were thrown to the floor in homes, groceries and liquor bottles thrown from shelves in stores, and one house was shifted several inches on its foundations. A few objects were toppled from shelves, pavements were cracked, and numerous landslides started in the vicinity of Kilauea Caldera, 45 miles from the epicenter.

At Napoopoo the ocean was observed withdrawing from shore, and most of the inhabitants of the village were hurriedly evacuated to higher ground until the possibility of a destructive tsunami was past.

Two small fires broke out. One was at Kaimalino, 0.3 mile south of Kealia, where kerosene, spilled in a kerosene-powered refrigerator, caught fire. The other was in Naalehu, where the earthquake upset a kerosene lamp. Both fires were quickly extinguished.

Bright flashes of white light at the time of the major earthquake were reported by persons at Naalehu and Pahala. These persons believe the flashes were not the result of electrical short circuits. Peculiar lights have occasionally been reported during other strong earthquakes.

During the night of August 21–22 persons in the central Kona area reported a distinct odor of hydrogen sulfide, apparently occurring in intermittent waves. The source of this odor is not known. No increase of fuming was observed at the vents of the 1950 eruption on the southwest rift of Mauna Loa.

Aftershocks in great number followed the major earthquake. The seismograph at Konawaena School was badly damaged by the first quake, so the total number of aftershocks will never be known. However, Mrs. H. Masuhara, at Keei, counted 109 felt earthquakes between the principal shock and nine o'clock the next morning. The Konawaena seismograph was repaired and restored to operation at 15:15 on August 23. It recorded 90 earthquakes during the next 24 hours and 494 earthquakes up to midnight on August 31. Most of these, of course, were too small to be felt, even close to the epicenter. Strong aftershocks occurred at 01:28, 09:56, 10:12, 18:32, and 22:48 (Hawaiian Standard time) on August 21, and at 17:15 on August 22. Only slightly less strong were those at 02:14 and 06:28 on August 22. Because of continued earthquakes, graduation ceremonies at Konawaena School on August 22 were held outdoors instead of in the auditorium.

INSTRUMENTAL DATA

The major earthquake dismantled all seismographs on the island of Hawaii. All but the Bosch-Omori seismograph in the Whitney Laboratory on the northeast rim of Kilauea

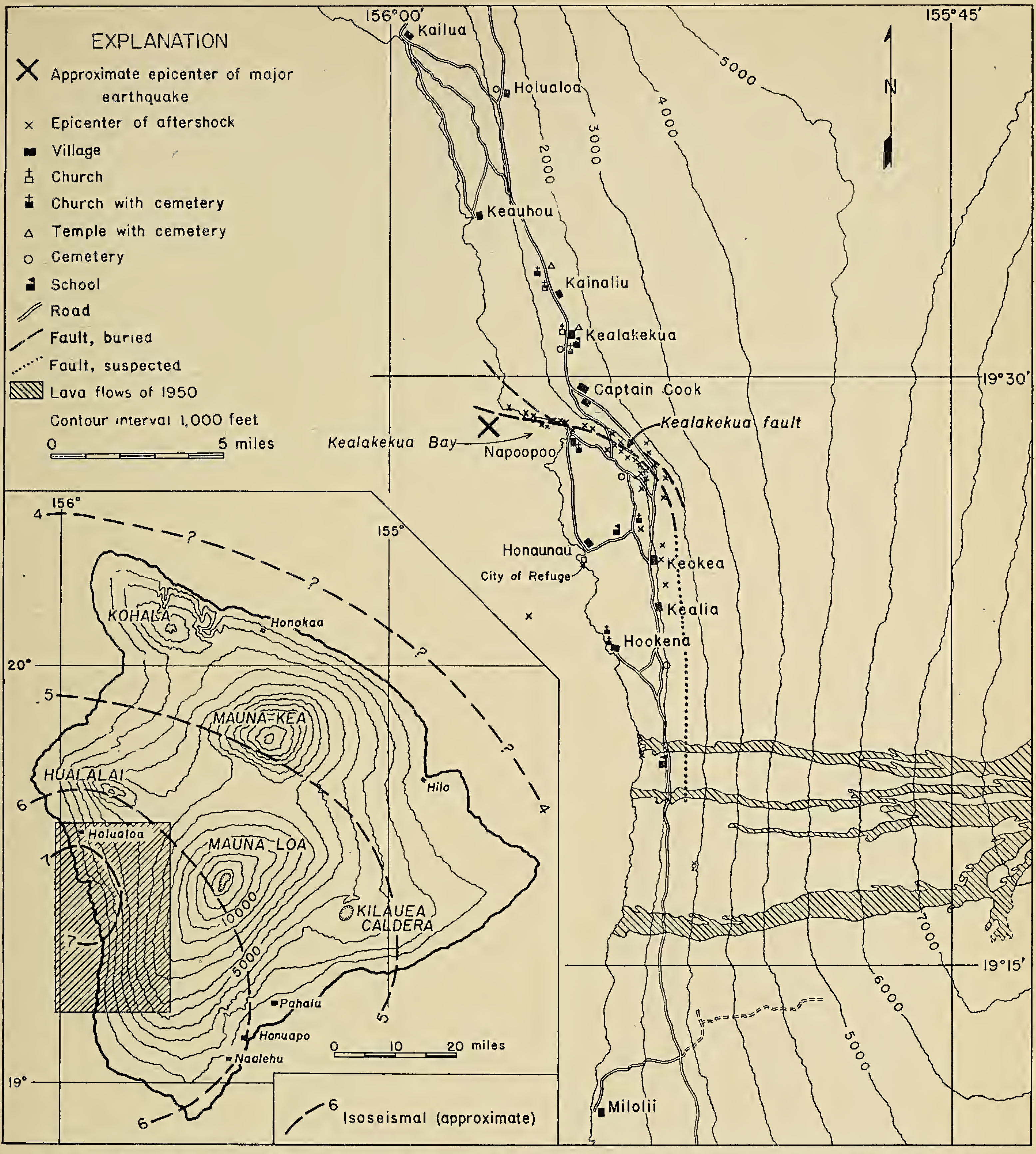

FIG. 1. Map of the central Kona district showing the location of places mentioned in the text and the approximate locations of the epicenters of the major earthquake of August 21, 1951, and of the aftershocks for which reasonably good locations were obtained. The inset map of the island of Hawaii shows the location of the area (shaded) covered by the other map and the approximate position of the isoseismal lines for the major earthquake.

Caldera were dismantled by the preliminary waves. Precise time control and, consequently, the precise time of arrival of the first waves are lacking on the Kona and Hilo instruments. As a result, instrumental data are inadequate for the close location of the focus of the earthquake. The duration of the preliminary waves on the north-south component of the Bosch-Omori instrument was 9.5 seconds, corresponding with a distance of approximately 47 miles from the Whitney Laboratory to the origin of the quake.

John C. Forbes, instrument maker at the Volcano Observatory, repaired the minor damage to the Bosch-Omori seismograph and put it back in operation at 01:24, 27 minutes after the first earthquake started. At that time the instrument was recording the long waves of a large earthquake. The period of these waves ranged from about 6 to 8 seconds and averaged approximately 6.7 seconds. Their maximum double amplitude was 67 millimeters, corresponding to a theoretical ground displacement of approximately 0.5 millimeter. These waves continued with gradually decreasing amplitude until 03:20. Because no other earthquake at an appropriate time was observed by more distant stations, it is believed that these long-period waves were the surface waves of the major Kona earthquake.

The time of origin of the major earthquake is given in the notice of preliminary determination of epicenter issued by the U. S. Coast and Geodetic Survey as $00^h56^m57.5^s$ Hawaiian Standard time ($10^h56^m57.5^s$ Greenwich Civil time). The time of beginning of registration of the preliminary waves at the Whitney Laboratory at Kilauea was 00^h57^m 09.5^s Hawaiian Standard time.

The direction of the first ground movement at Kilauea Caldera was east-southeast and up, that at the Mauna Loa station was east-northeast, and that at the Kealakekua station was east-northeast. At the Kealakekua station the north-south component was only slightly damaged, but on the east-west component the suspensions were broken and the weight dropped on the floor 2 feet west of the pier.

The Kona seismograph, at Konawaena School (Fig. 1), was restored to operation at 15:15 on August 23. Previous to that time, location of the points of origin of the aftershocks on an instrumental basis was uncertain because of the very short base of the triangle formed by the intersection of lines from the earthquake foci to the other stations. Earthquakes after that time are fairly well located because of the control given by the Kealakekua seismograph. Most of these were located by means of data from four stations: Kealakekua, Mauna Loa, Hilo, and Whitney (Kilauea).

Locations of the epicenters of aftershocks which occurred after 15:15 on August 23 with serial number greater than 190 are shown in Figure 1. Thirty-three such aftershocks have been located with small probable error. Most of them fall on or close to a fault that runs out to sea in a west-northwesterly direction along the northern edge of Kealakekua Bay. The existence of this fault, partly buried by later lava flows, has been recognized for many years (Dana, 1890: 30; Stearns and Macdonald, 1946: 37, pl. 1). At its eastern end it bends southward, and the writers have suspected that the abnormally steep lower western slope of Mauna Loa inland from the highway for 15 miles or more south of Captain Cook is a fault scarp deeply buried by later lava flows. An interesting partial confirmation of this theory is furnished by the location of the epicenters of several aftershocks along this line (Fig. 1).

The frequency of aftershocks decreased rapidly from August 23 to September 4. As is shown in Figure 2, the average frequency then decreased very slowly until the end of September. No figure is available for September 7 because of mechanical failure in the recorder at the Kealakekua station. The apparent depth of origin of the aftershocks ranged from 3 to 12 miles, most being about 6 or 7 miles. No progressive change of depth with passage of time is apparent.

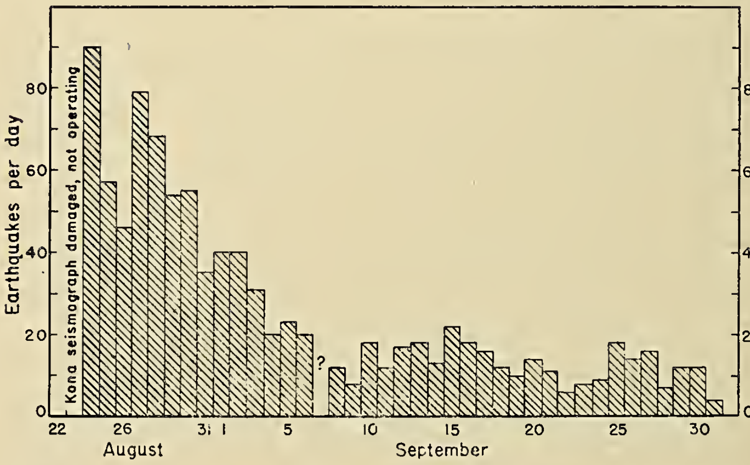

FIG. 2. Graph showing frequency of aftershocks to the end of September, 1951.

Altogether, from the time it was put back in operation until the end of August, the Kealakekua seismograph recorded 494 earthquakes, and until the end of September 965 earthquakes. Nearly all of these are regarded as aftershocks of the big earthquake of August 21. Most were too small and shallow-seated to be recorded at the other stations, hence their foci could not be closely located. It appears certain, however, that most originated along the Kealakekua fault at the northern edge of the Kealakekua embayment.

EFFECTS OF THE EARTHQUAKE

Description of Terrane

The epicentral area lies on the western slope of Mauna Loa, a few miles south of the surficial boundary between Mauna Loa and Hualalai Volcanoes. It is transversed from north to south at altitudes of 1,000 to 1,300 feet above sea level by the main highway, from which roads lead to the shore at Napoopoo, Honaunau, Hookena, and Milolii (Fig. 1). In the vicinity of the highway the average slope of the land surface is about 10 degrees, which is several degrees steeper than the average for Mauna Loa slopes in general. Above an altitude of 5,000 feet the average slope decreases to about 7 degrees. The steepness of the lower part of the slope is believed to result from an ancient fault scarp deeply buried by more recent lava flows.

In the area within 6 miles south of Napoopoo the steep zone is narrower and more sharply defined than farther south, and west of it the slope again flattens toward the sea. Three miles east-southeast of Napoopoo the steep zone turns sharply northwestward and becomes even steeper, taking on the unmistakable characteristics of a fault scarp mantled by more recent lava flows. This scarp forms the northern boundary of Kealakekua Bay, and there the older lava beds in the scarp are not mantled by later flows.

The steep seaward slope results in a distinct asymmetry of the terrane, which asymmetry of necessity extends to nearly all structures on the terrane. Buildings rest on foundations that are high on one side and low on the other. Roads in many places rest on a cut on one side and fill on the other, or on a fill which is shallow on one side and deep on the other. Stone walls parallel to the coast have one sloping side shorter than the other. All of this results in a lesser degree of stability than in structures built on level terranes, and in a favored direction of unstability. Partly because of the higher foundations and deeper fills on the seaward side and partly because of the continuous effect of gravity, structures tended to move downhill during the earthquake regardless of the direction of the actual shaking. This effect must be considered in using the direction of displacement of objects as a means of locating the epicenter.

Rock Slides

Many small rock slides in highway cuts were caused by the earthquake. Most of them came from cuts on the inland side of the highway, probably largely because the cuts were higher on that side. Most of the slides were small, bringing down blocks less than 2 feet across. These caused little damage and were easily removed. A few larger slides brought down large blocks weighing several tons, the removal of which required the use of bulldozers or other heavy equipment. The large slide farthest from the epicenter occurred at a high roadcut just west of Honuapo, 40 miles from the epicenter. Small slides and rock falls in road cuts extended all the way to Kilauea Caldera, 44 miles from the epicenter. Many small rock avalanches took place in Halemaumau Crater during and for several days after the earthquake.

A large part of the damage to road cuts did not, strictly speaking, result from sliding of the materials. Most of it was merely a fraying of the banks by the rolling down of loose or semiloose material. Few of the highway cuts exceeded 5 feet in height, and few

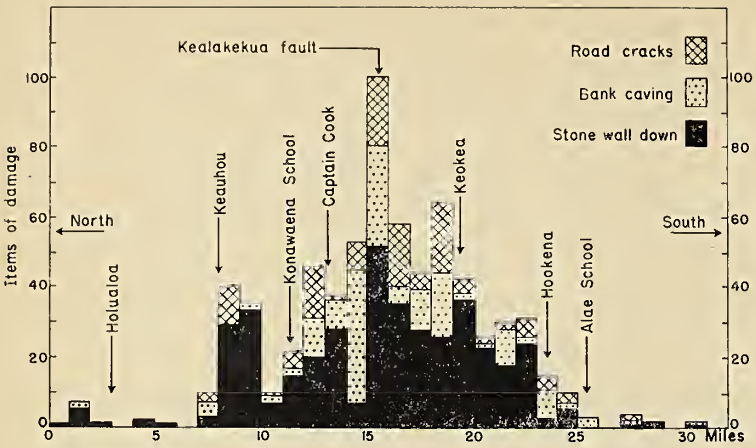

FIG. 3. Diagram showing the frequency distribution of three of the principal types of earthquake damage along the main highway. The arrows indicate the position on the highway of some villages and other features. Note the centering of damage close to the Kealakekua fault.

were dressed back to any approximation to an equilibrium slope. The earthquake of August 21 greatly exceeded in size any previous quake in the affected area since the road cuts were made, and shaking during the earthquake merely dislodged much of the loose material and allowed it to roll down onto the road.

The distribution of abundance of rock slides in road cuts is shown in Figure 3, in which it is represented by the portion of the columns labeled "bank caving." Like the other damage shown in the graph, it was greatest in the immediate vicinity of the Kealakekua fault, inland from and a little south of Kealakekua Bay.

Many large slides took place on the fault scarp at the northern edge of Kealakekua Bay. The slides caused a disturbance of the water of the bay just after the earthquake, and many residents of the coastal village of Napoopoo fled inland, fearing a big tsunami. Slides continued on the Kealakekua cliff for several days after the earthquake, sending up clouds of yellowish-brown dust, leaving fresh scars on the cliff face, and building talus fans at the foot of the cliff.

Less numerous and smaller slides also occurred along the cliff just inland from the village of Hookena Beach. The cliff at Hookena is believed to be an ancient fault scarp, mantled by lava flows from the upper slopes of Mauna Loa during prehistoric times. Many fragments of the lava veneer were shaken down during the earthquake.

Tsunami

Despite early reports to the contrary, there is no doubt that the earthquake was accompanied by a small tsunami, or "tidal wave." At Napoopoo wharf the water was observed to withdraw from shore. The tide was low at the time. Withdrawal of the water lowered the level to about 4 feet below normal low-tide level. Immediately afterward the water returned shoreward, and the level rose about 2 feet above low-tide level.

At Milolii, Eugene Kaupiko reported that a few minutes after the earthquake, which he felt while in a canoe anchored offshore, the water receded from shore, revealing the sea bottom as far out as the edge of the wharf. This represents a lowering of the water level of about 3 feet. After the withdrawal the water returned shoreward, causing a rise of the water level 3 or 4 feet above normal low water and floating away a canoe that had been drawn up on the beach about 2.5 feet above high-tide level. One large fall and rise of the water level appears to have been followed by many small oscillations.

At Honaunau, between Napoopoo and Milolii, Eli Cooper, caretaker of the City of Refuge, went down to the water's edge a few minutes after the earthquake. At that time he could see no signs of disturbance of the water, but a small tsunami could have occurred between the time of the earthquake and his arrival at the strand. At Hookena no tsunami was observed, and there was none large enough to flood the floor of the dock, about 4 feet above normal water level. However, it cannot be said definitely that no small tsunami occurred there.

The Honolulu tide gauge record shows a distinct oscillatory disturbance of the water starting at approximately 01:35, about 38 minutes after the earthquake. Seven or more oscillations are detectable, with an average period of about 14 minutes, reaching an amplitude from crest to trough of 3.6 inches. This undoubtedly is the record of a seiche set up in Honolulu harbor by the tsunami. Using the time of beginning of the disturbance at Honolulu as that of arrival of the tsunami, the average speed of travel of the tsunami from the epicenter to Honolulu was approximately 284 miles an hour. The time of beginning of the disturbance at Honolulu corresponds well with the calculated theoretical arrival time of a tsunami caused by the Kona earthquake, so there can be little doubt the disturbance was of that origin. A similar disturbance is shown on the record of the Hilo tide gauge. The time of beginning of the disturbance at Hilo is less definite, but appears to have been about 02:38. This corresponds with a much slower average speed of travel of the tsunami, of about 78 miles an hour, as the waves were refracted around the island in comparatively shallow water.

Damage to Buildings

Shortly after the earthquake the Kona police estimated that about 200 houses in the area had suffered some degree of damage. Most houses in the area near the epicenter are of frame construction, set on knee-braced timber underpinning. Such supports proved capable of undergoing the shaking and distortion caused by the earthquake without serious damage. Most of the damage was minor and quickly repaired. Some houses shifted from a fraction of an inch to 3 or 4 inches on their foundations. Many were sufficiently twisted out of line to make it difficult or impossible to close windows and doors. In nearly all houses dishes and other objects were thrown from shelves. Only the more seriously damaged structures are enumerated here.

At Kaimalino, 0.3 mile south of Kealia (Fig. 1), a shop building collapsed. This building was placed on timber supports level with the highway in front but 6 feet above ground level in back, without adequate cross bracing. Failure of the underpinning allowed the building to tilt backward and slump to the ground (Fig. 4). A similar situation was found at Keokea, 1.2 miles north of Kealia, where a service station building slumped downhill away from the highway and partly collapsed.

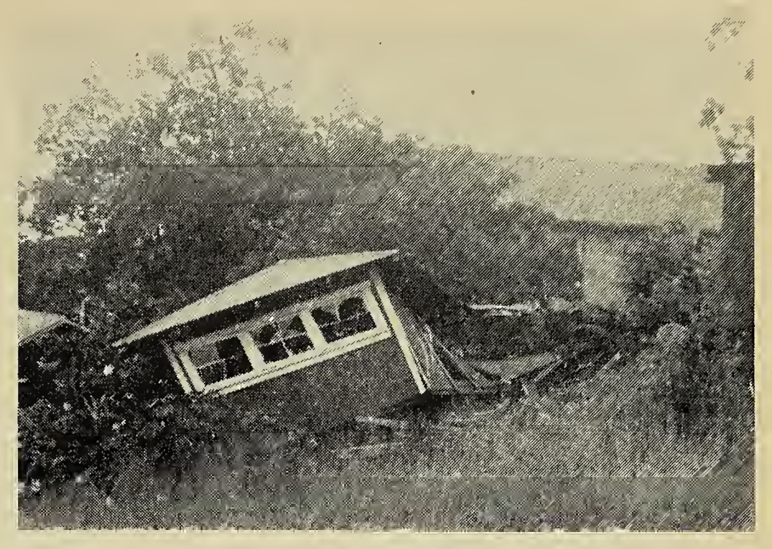

FIG. 4. Overthrown shop building at Kaimalino, from the south.

In the Kahauloa area, about 1.7 miles east of Napoopoo village, the walls of a store partly collapsed as a result of distortion of the building caused by shifting on its foundation. The warehouse of another store was badly damaged.

At Hookena Beach two old frame houses were destroyed. One, which had been occupied briefly in 1889 by Robert Louis Stevenson, fell when its timber underpinning failed, and collapsed. The other also was dropped onto the ground by collapse of its underpinning. It appears to have fallen almost straight downward. The building was somewhat twisted, but not otherwise seriously damaged. At Kealia and at Kiilae, about 0.4 mile south of Kealia, two other frame houses were badly damaged by collapse of their timber underpinning. All of these cases of collapse of frame houses appear to have been caused by inadequate bracing or poor materials in the underpinning, in some instances probably aggravated by insecure footings.

The cases of structural damage most distant from the epicenter occurred at Naalehu, 36 miles southeast of Napoopoo, where wallboard in a restaurant was cracked, and one

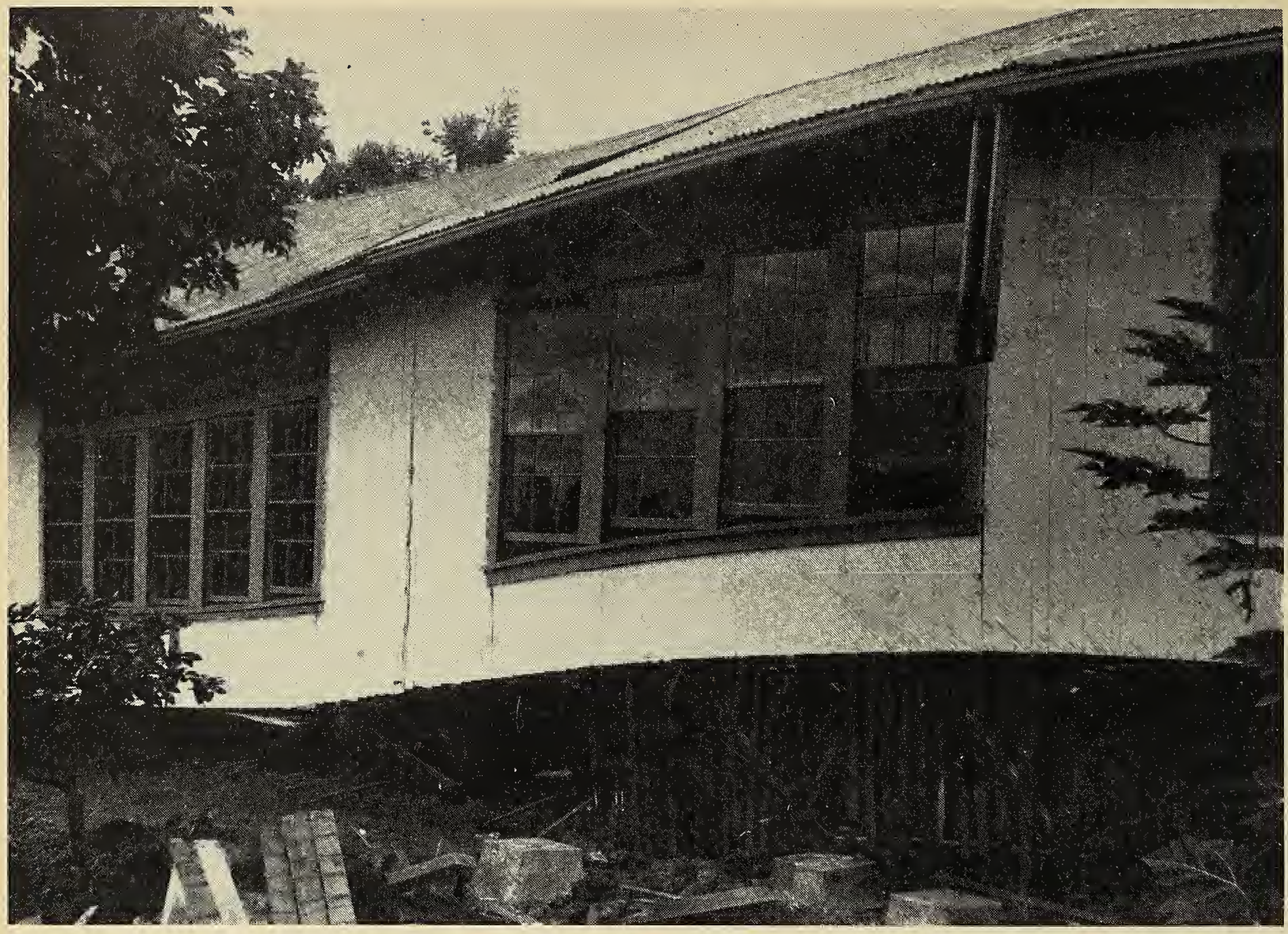

FIG. 5. Central portion of Honaunau School, from the southwest. All but the south end of this building was let down and moved westward owing to inadequate bracing of the underpinning in an east-west direction transverse to the longer dimension of the building.

house was moved several inches on its foundation.

A striking example of the effect of poorly designed underpinning is furnished by the Honaunau School. This was a long, narrow frame building placed with its length parallel to the contour of the ground surface. The front of the building was about 3 feet and the back about 10 feet above ground level. It was supported on timber posts. The posts and knee bracing parallel to the length of the building were entirely adequate, but there was comparatively little bracing parallel to the shorter direction of the building, and some of this was fastened not to joists but to floor boards. As a result, the underpinning was deficient in stiffness in the direction parallel to the ground slope. The direction of shaking during the earthquake was nearly parallel to this direction of weakness in the structure, and the swaying of the structure caused the underpinning to fail in part and to allow the building to slump downhill onto the ground (Fig. 5). The building is considered a total loss.

There were several church buildings with masonry walls in the area near the epicenter. Most of these suffered some damage, and some were very seriously damaged. The masonry consists of fragments of lava rock laid with a mortar made by calcining coral limestone. In some there was very little mortar in the inside parts of the wall. Most of the buildings were more than 95 years old.

The Central Kona Church at Kealakekua suffered cracking of the interior plaster on the east and west walls, but the masonry showed little or no cracking. At the back of the church is a small lean-to addition, the roof of which is supported by beams with one end set into niches in the wall of the main building. During the earthquake there was enough differential movement of the two portions of the building to pull the beams out of their supporting niches and allow the roof of the addition to drop a few inches. At the front of the church is a tower covered with exterior plaster. The tower and main church building are essentially separate structures and appear to have moved independently during the earthquake. The plaster of the tower was badly cracked.

St. Paul's Church at Honalo, 1.9 miles north of Kealakekua, suffered severe cracking of the masonry in both the main building and the rectory. Kahikolu Church, at Napoopoo, suffered surprisingly little damage. The lintels and interior plaster showed some cracking, but the masonry was unharmed.

The Protestant church at Hookena Beach was badly damaged. The building consisted of masonry walls and a sheet-iron roof, supported on heavy handhewn beams which in turn were supported by east-west beams resting in niches on the upper edge of the front and back walls. During the earthquake nearly the whole front (west) wall was thrown out, some debris being as much as 25 feet from the building (Fig. 6). The other walls were not appreciably damaged, even the interior plaster being almost uncracked. It appears possible that during the quake the roof may have tended to move as a separate unit from the rest of the structure and, by its tendency to lag behind during the initial violent eastward movement of the ground, may have pushed out the front wall.

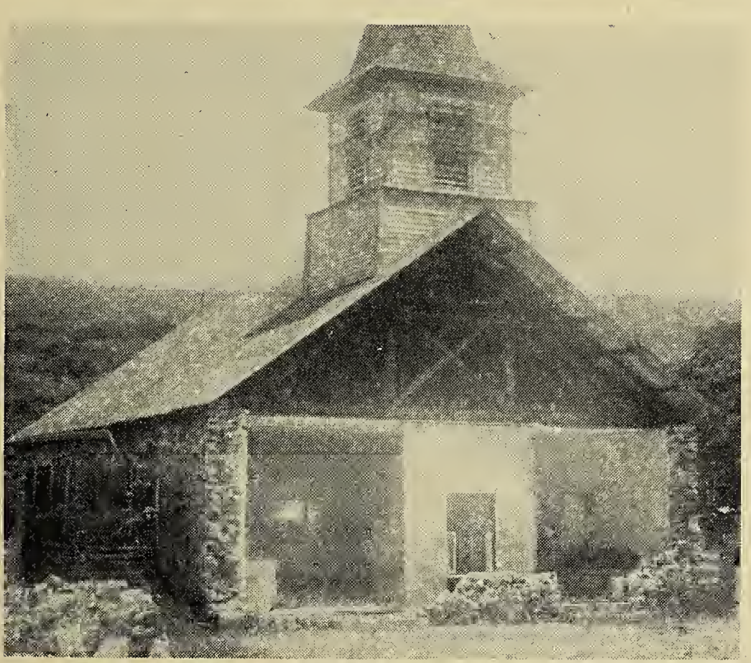

FIG. 6. West end of Pukaana Church at Hookena Beach showing complete demolition of masonry wall of this 100-year-old structure. Much of the debris was cleared away soon after the earthquake. No nearly comparable damage to this building is known to have taken place during the century since it was built.

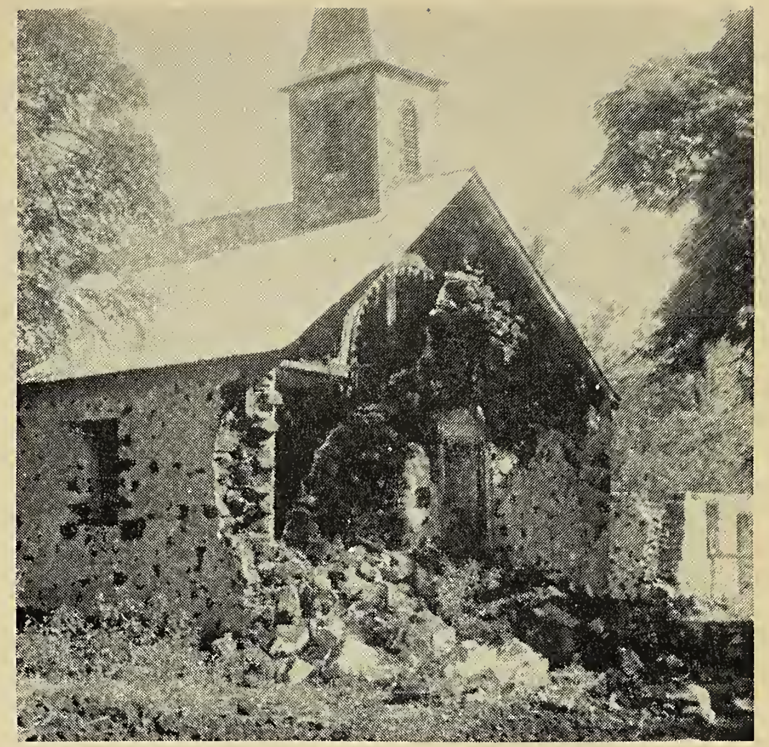

FIG. 7. Catholic Church 0.6 mile north of Hookena Beach, from the northwest. The east end of this church was similarly thrown down and outward, to the east. The near corner and the corresponding corner of the small building, already without a roof, suggest displacement most markedly to the northwest, in the general direction of the epicenter.

Similarly, a small stone building nearby, which had long been without a roof as is shown by trees growing within the walls, had both its end walls thrown outward, to west and east, while the side walls remain standing though somewhat cracked.

The Catholic church 0.6 mile north of Hookena Beach was very heavily damaged. The upper portions of both the east and west walls were thrown down (Fig. 7), and the interior plaster on all walls was badly cracked. However, the walls were built merely of loose stones laid together without mortar between them except close to the faces, where the interior and exterior plaster had penetrated a short distance. Considering the type of construction, probably the most surprising feature is that the building had not collapsed previously in one of the strong earthquakes which occur in Kona every few years.

The lessons to be learned from the structural damage caused by the earthquake are those which have been taught by many strong earthquakes elsewhere. A large proportion of the damage results from poor construction or from poor or inappropriate materials. Unreinforced masonry structures are inadvisable in any area subject to strong earthquakes. Footings should be firm, and construction materials, particularly the underpinning, should be sound. Cross bracing, particularly of underpinning, should be adequate in all directions. The best insurance against earthquake damage is good construction.

Damage to Water Tanks

Practically all dwellings in the Kona area are equipped with water tanks for storage of rain caught on the roof. Nearly all these tanks were of wooden stave construction. A large number of these round, tub-type tanks were destroyed or damaged by the earthquake.

The few metal and masonry tanks were undamaged. Because of their importance, not only in Kona but in many Hawaiian communities, a special study of damage to these tanks has been undertaken. The results will be published elsewhere. Only a brief summary is given here.

Altogether, approximately 200 tanks of a total of more than 1,000 in the heavily shaken area were damaged or destroyed by the earthquake. Tank damage extended from Keauhou on the north to Milolii on the south and was most severe in the area from Captain Cook to Hookena. Tanks showed all degrees of failure, from the development of slight leaks to complete collapse. A few tanks may, at least in part, have been pushed over by neighboring structures. Thus, the tank at the southern end of the Honaunau School building (Fig. 8) may have been partly pushed westward by the collapse of the adjacent building, to which it was connected by a rigid wooden down-spout. However, most of the damaged tanks appear to have failed because of their own behavior during the earthquake. The commonest features contributing to tank failure appear to have been poor footings and inadequate cross bracing of the underpinning.

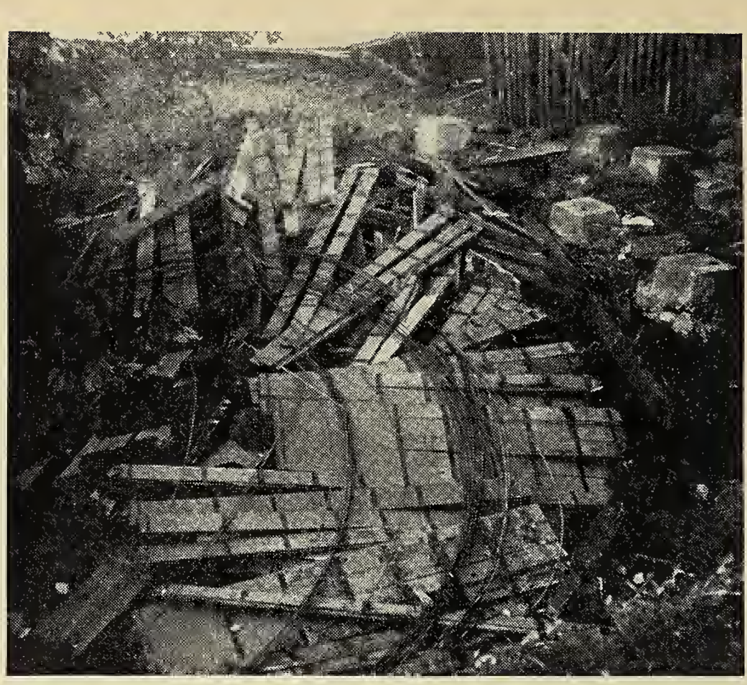

FIG. 8. Demolished tank west of the south end of Honaunau School, footings on which the tank formerly stood, and part of the school building, from the southwest.

Damage to Stone Walls

The loose stone walls characteristic of the Kona area were extensively damaged by the earthquake. The principal damage was in the area between Keauhou, 3.5 miles north of Kealakekua, and Pahoehoe, 3 miles south of Hookena (Fig. 1). However, isolated instances of wall derangement were observed as far north as Honokahau, 16 miles north of the epicentral area, and Naalehu, 36 miles southeast. The distribution of damage to walls is shown graphically in Figure 3. Many miles of wall required rebuilding. Since the cost of contract rebuilding is approximately a dollar a yard, the total monetary loss from the destruction of walls is considerable.

Most of the stone walls in the area consist of irregular fragments of clinkery aa lava less than a foot across. A few walls have bases of blocks a foot or more long reaching halfway or more through the wall, and, especially in the older walls, occasional slabs are laid partly or entirely through the wall to help tie it together. Because of the rough, irregular surfaces of the fragments it is possible to build them into a nearly vertical wall 3 or 4 feet high and only about 30 inches thick at the base. Such walls stand well under ordinary conditions, but, because of the shortness of the bonding surfaces of adjacent blocks, they are rather unstable under any joggling, such as by earthquakes. The earthquake of August 21 caused extensive shaking down of the walls. The commonest type of damage was a slumping of the upper part of the downslope face of the wall, the fragments rolling down and out a short distance from the base of the wall. Such damage was especially common on the north-south trending walls and at high places on the walls. In a few instances, walls on nearly level ground were dislodged almost equally in both directions, but the failure was preponderantly on the west side of the walls, and the material from the walls was displaced westward.

Some of the westward displacement of material probably resulted from the tendency of the loose material composing the wall to lag behind during the initial strong eastward movement of the ground. However, a large proportion, perhaps most, of the failures of the walls on their west side undoubtedly resulted from the fact that, because of the general westward slope of the ground, the west side of the wall was higher and usually steeper than the east side, and there was a tendency for materials to shift downslope under the influence of gravity.

Well-built walls were surprisingly resistant to earthquake damage. Thus, the wall along the landward side of the highway from Honaunau to Napoopoo, built of carefully placed rectangular blocks of lava, was almost wholly undamaged despite its location very close to the epicenter. Likewise, in other parts of the epicentral area, older walls in which slabs extending through a large portion of the wall had been used to tie the wall together showed comparatively little damage.

At the ancient City of Refuge at Honaunau, about 20 feet of the seaward side of the main outer wall of the enclosure collapsed. It is interesting to note that damage was restricted to a reconstructed portion of the wall, whereas the remaining portions of the original enclosure wall and the walls of the heiau platforms were undamaged. Homer Hayes, a close student of the City of Refuge, has made the highly plausible suggestion that the peculiar construction of the ancient walls, in which occasional broad slabs extend entirely or largely through the wall and sometimes bridge open spaces beneath, is responsible for the greater resistance to earthquakes of the old portions of the wall.

Damage to Roads

Damage to paved roads was of three general sorts: (1) cracking of pavement, (2) cracking and slumping of shoulders and separation of shoulders from pavement, and (3) collapse of road cuts, causing partial obstruction of the road. The latter has already been discussed under the heading "Rock Slides." Minor cracking of shoulders occurred over an area extending about 10 miles north and 12 miles south of the approximate epicenter, and a few cracks were formed as far away as the northeast side of Kilauea Caldera, 47 miles from the epicenter. However, extensive pavement cracking and slumping were restricted to the area between Captain Cook and Hookena. The distribution of cracks in the road is shown in Figure 3.

Observed cracking or slumping of the pavement or shoulders was entirely restricted to portions of the road on fills. In building the road, some gullies were crossed by laying in a rock fill having a batter, or departure from vertical, of less than 1 in 4, filling with fine material, and laying asphalt pavement across the top. Such fills were insufficiently stable to withstand the shaking of a strong earthquake, and in several places the down-

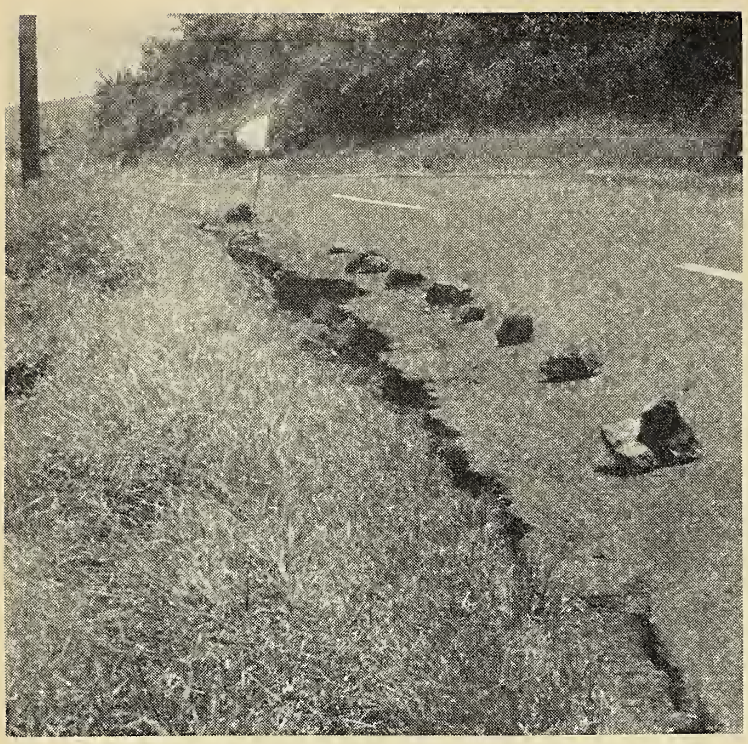

FIG. 9. Crack along roadside south of Kealakekua, from the south, showing separation of embankment from edge of pavement due to slumping.

slope face of the fill was dislodged, allowing the material of the road bed to settle, cracking the pavement. In other places the fill appears to have settled a little merely by compaction during the jostling by the earthquake, causing cracks in the pavement.

A common occurrence was the formation of a crack parallel to the edge of the pavement on its downslope side, either within the pavement a few inches from its edge or between it and the shoulder (Fig. 9). Some of these were as much as 75 feet long and 8 inches wide. This appears to have resulted from a downslope lurching of the shoulder, moving as a separate unit from the portion of the fill beneath the pavement. The independence of movement of the shoulder and pavement was interestingly shown along the highway about 2 miles southeast of Captain Cook, where soil and sod on the shoulder were overthrust as much as an inch onto the pavement.

Damage in Cemeteries

Many headstones in cemeteries in the area near the epicenter were deranged by the earthquake. As a part of the general earthquake investigation, these cemeteries were examined, and a rough statistical study of the damage was made. Unfortunately, owing to shortage of personnel and pressure of other duties, we were delayed several days in making the cemetery examinations, and some restoration of headstones had already taken place in some cemeteries before we visited them. However, in most cemeteries little restoration had been done, and the damage remaining was probably a representative sample of the original damage. It is believed that practically all stones which had been dislodged could be detected, even after they had been replaced, by breaks or scratches on the stone or disturbance of the cement bond at the base of the stone.

There are more than 50 cemeteries in the area, but most are small family or church plots with few graves and have not been used in recent times. In some places burial was in vaults without headstones or with headstones or markers firmly cemented in place and not readily susceptible to damage by an earthquake of the intensity of the one under study. Most of the valuable information came from a few of the larger cemeteries. Damage at these is summarized in the accompanying table, and their locations are shown in Figure 1.

Derangement of headstones included overturning of stones and shifting of stones on their bases with or without rotation. In addition many grave caps were broken, some by falling or disturbance of headstones and some by lurching or slumping of the adjacent subsoil. The latter type of damage was particularly prevalent on steep slopes, where the subsoil is thick and loose. Damage of all sorts was restricted to the area between Honalo and Honokua, 5 miles northeast and 10.5 miles south-southeast, respectively, of the probable position of the epicenter.

In cemeteries north of Keauhou no damage or derangement was noted. Two miles south of Keauhou, at Lanakila cemetery in Lehuula, 4 of the 15 headstones were dislodged to the west. Inland and slightly northward, at the Daifukuji Mission in Honalo, about 5 miles

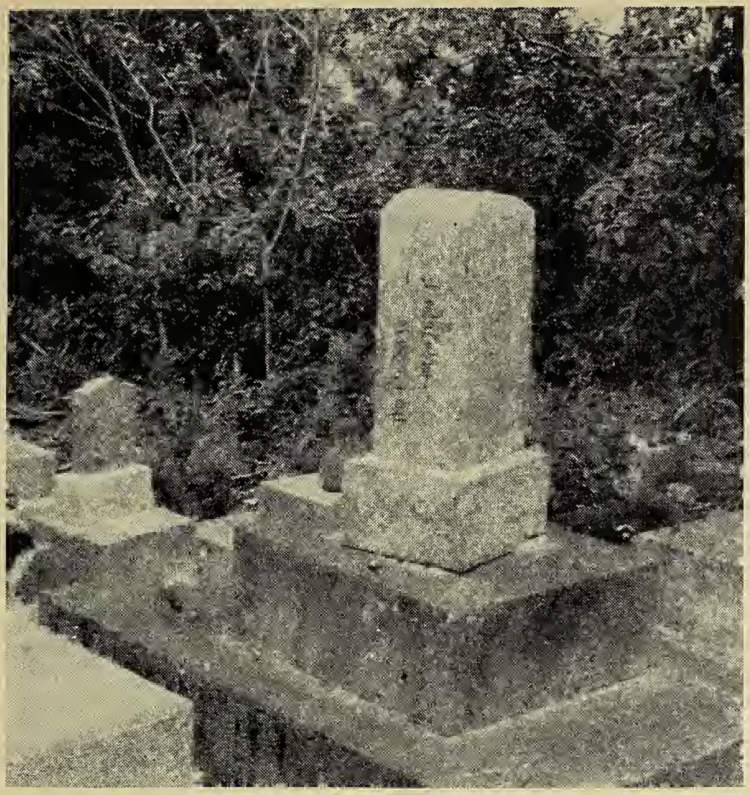

FIG. 10. Gravestone rotated counterclockwise, in Daifukuji cemetery, Kainaliu, looking approximately northwest.

north of Napoopoo, of an estimated total of 150 grave markers, 6 toppled west, 7 north, 2 east, and none south. Six had been shifted north, 16 were twisted counterclockwise, and 2 clockwise; 8 grave caps were broken (Fig. 10). It was reported that many more had been disturbed but had been restored.

At Hongwanji Mission, Kealakekua, with more than 600 graves, 12 headstones were overthrown to the west, 9 to the east, and none to the north or south. Thirty-four were twisted clockwise, 11 counterclockwise, one each shifted north, west, and south; 22 grave caps were broken.

At the Central Kona Church cemetery at Kealakekua, 12 headstones and one large memorial monument were overturned westward and one stone eastward. Another stone was rotated counterclockwise. In the Episcopal cemetery, just across the highway, five headstones were overturned westward, one was rotated counterclockwise, and one clockwise.

At Kahikolu Church, about 0.5 mile south of the Kealakekua fault line, of a total of 10 headstones, 2 were overturned to the west and one was twisted clockwise. Two miles farther inland but only about 0.6 mile south of the fault line is another cemetery of the Hongwanji Mission. Here, of more than 200 headstones, 29 were still down on September 7, the majority having been dislodged to the west, and 10 or more had been replaced. Thirteen had been twisted clockwise and 4 counterclockwise; 24 grave caps were broken. There was much damage to caps and markers in the lower section of the cemetery where the ground is composed of rocky talus.

At St. Benedict Church, 1.5 miles farther south, there is a cemetery with approximately 100 markers. Nearly half of these are wooden crosses, which were not deranged. Several others are light concrete crosses with wire reinforcing. Some of these were broken at the shank so as to expose the wires one or two of which were the sole remaining support. Of about 20 vertical headstones, 11 were displaced or broken.

The most complete derangement of gravestones was found in the Kalahiki Japanese cemetery, a small hillside cemetery 3.8 miles south of Kealia, where only 2 of 30 markers were found in position 5 days after the earthquake (Fig. 11). The dislodgement was chiefly to the southwest and, to a lesser extent, to the northeast. Ten were shifted to the north without being thrown down. Seven, including some of these 10, were rotated clockwise and one counterclockwise. Here, on loose, steeply sloping ground, a large proportion of the grave caps were broken, owing to poor design and to construction on the newly heaped grave mound. This cemetery is about 11 miles south of the probable epicenter. South of this point no cemeteries with headstones susceptible to overturning or rotation were found.

The prevailing east-west azimuth of fall of gravestones throughout the area is probably largely the result of the prevailing westward slope. The orientation of most cemeteries is governed by the general north-south alignment of the principal roads, and, in turn, most gravestones face the west or east and have

TABLE 1

SUMMARY OF DAMAGE IN CEMETERIES IN AREA EXAMINED

NAME	LOCATION	DISTANCE AND DIRECTION FROM NAPOOPOO	APPROXIMATE NUMBER OF HEADSTONES	HEADSTONES OVERTURNED						HEADSTONES ROTATED	
				NUMBER	PER CENT	APPROXIMATE DIRECTION				CLOCKWISE	COUNTER-CLOCKWISE
						N	E	S	W		
		miles									
Holualoa Japanese	Holualoa	10 N	300	0	0	0	0	0	0	0	0
Daifukuji	Honalo	5 N	150	15	10	7	2	0	6	2	16
Lanakila Church	Kainaliu	4.5 N	12	4	33	0	0	0	4	0	0
Hongwanji Mission	Kealakekua	3 N	600	21	3.5	0	9	0	12	33	10
Central Kona Church	Kealakekua	2.5 N	30	12	40	1	0	0	11	0	1
Christ Church	Kealakekua	2.5 N	60	8	13	0	3	0	5	1	1
Kahikolu Church	Napoopoo	0.5 S	10	2	20	0	1	0	1	1	0
Hongwanji Mission	Keei	1.5 SE	200	40	20	3	22	1	14	13	4
St. Benedict Church	Honaunau	3.5 SE	100	11	11	0	0	0	11	0	0
Japanese	Kalahiki	7.5 S	31	20	64	1	6	1	12	14	1

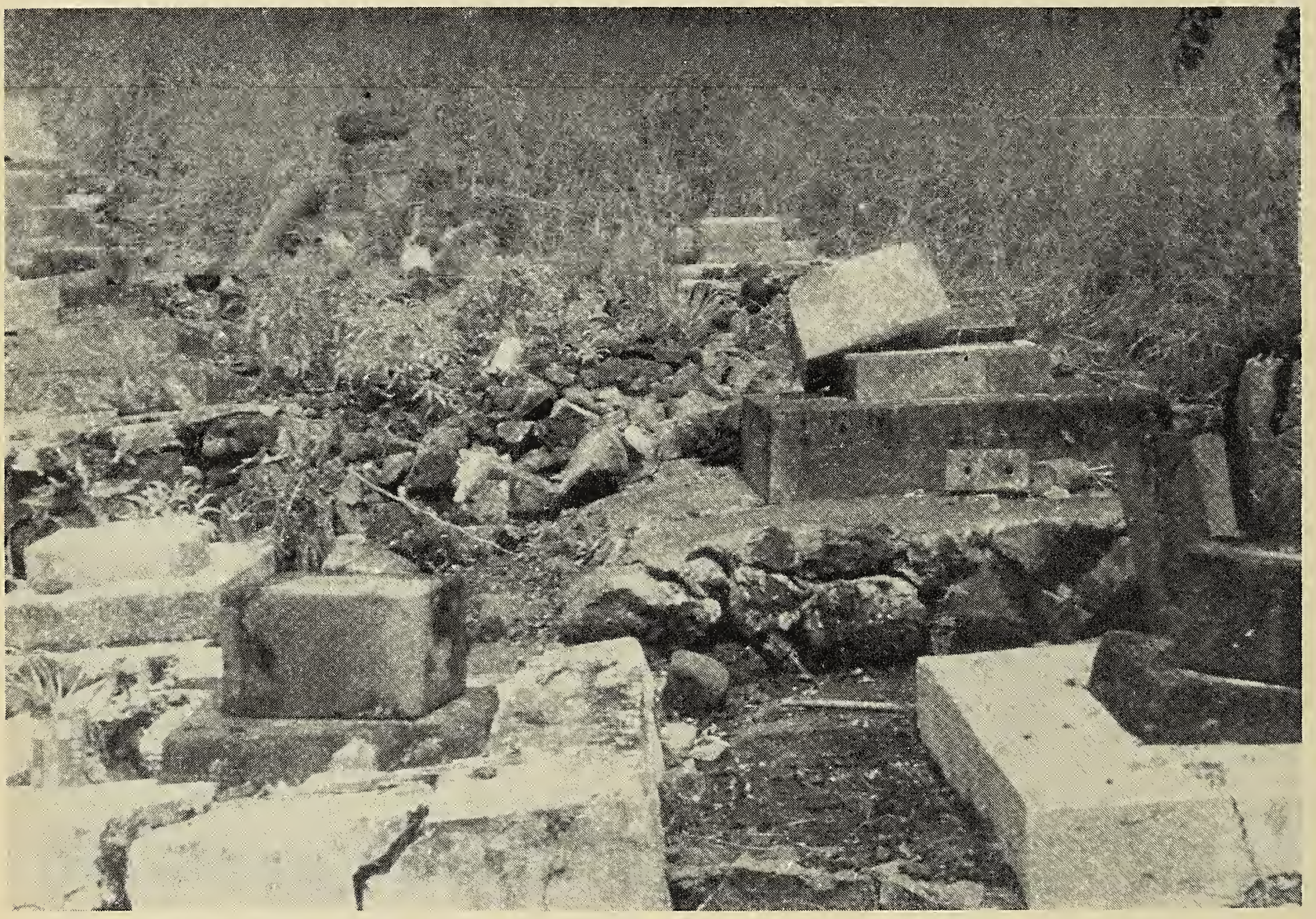

FIG. 11. Broken bases, displaced base stones, and overturned headstones in Kalahiki Japanese cemetery, south of Kealia, looking southeast. Partly because of unstable hillside ground and partly because of proximity to the epicenter, damage in this cemetery was widespread and severe; scarcely a grave escaped marked derangement.

the long dimension of their base oriented north-south. Therefore, the stones rock in an east-west direction much more easily than in any other, and, consequently, the most likely azimuth of fall is east-west. Furthermore, under sustained shaking, there is a tendency for all loose objects, including the soil cover, to work downslope to the west under the influence of gravity.

Rotation of Columns

Imamura (1937: 96) has shown that the direction of rotation of short rectangular columns, such as many headstones are, can be useful in determining the direction of motion during an earthquake and, consequently, the approximate azimuth of the line toward the epicenter. If the earthquake motion is parallel to the sides or to the diagonal (A—B, inset, Fig. 12) of the column, rotation probably will not occur. However, if the earthquake motion is in some intermediate direction, such as E—E′ in Figure 12, a rocking of the column will be accompanied by a rotational tendency. A ground motion in the direction E′ will cause the column to rock on the corner B. At the same time, the resultant of the force E′ in the direction CD will tend to rotate the column about the corner B in a counterclockwise direction. Similarly, a motion in the direction E will tend to cause a counterclockwise rotation about corner A. Directions of earthquake motion lying in the unshaded octants of the diagram tend to cause counterclockwise rotation of the column, and directions of motion in the shaded octants tend to cause clockwise rotation.

However, this law of rotation can be, and commonly is, upset by other conditions. Inhomogeneity of the terrane may cause the principal motion to be, locally, in a direction other than the azimuth pointing directly to the epicenter. Also, excentric irregularities in the bottom of the monument or its underlying base, or in the adhesion between the monument and its base, may result in rotation around those irregularities independent of the rotation described above.

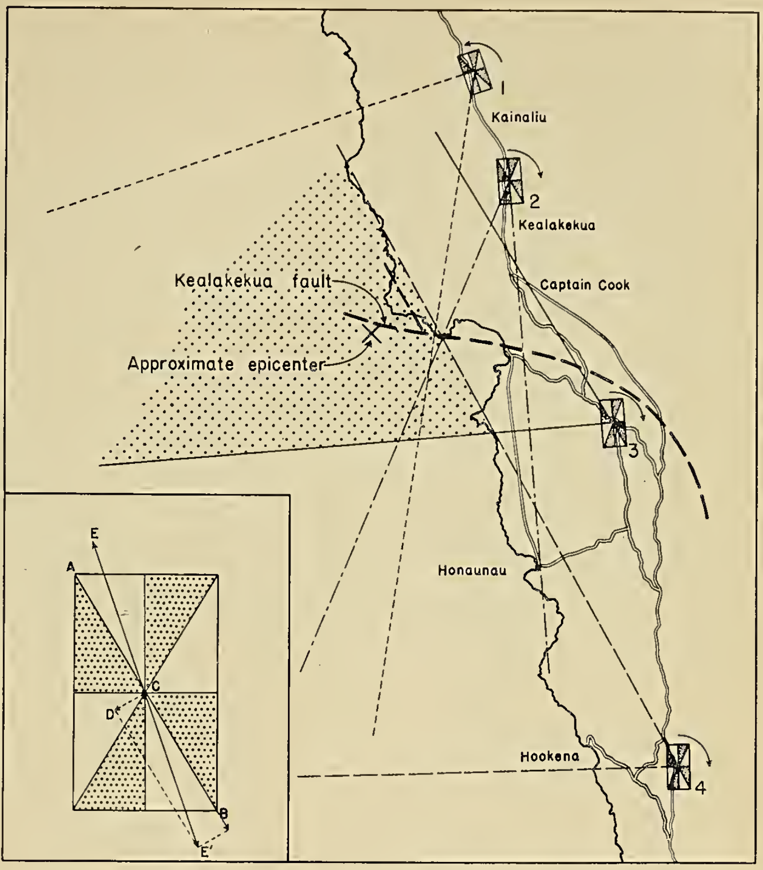

FIG. 12. Map of the central Kona area, showing the prevalent direction of rotation of monuments in cemeteries. The cemeteries are: 1, Daifukuji, Honalo; 2, Hongwanji Mission, Kealakekua; 3, Hongwanji Mission, Keei; 4, Kalahiki Japanese. At each cemetery the arrow indicates the prevalent direction of rotation. The boundaries of the octants containing the direction toward the epicenter are prolonged. The stippled area west of Captain Cook is that in which three or more of the octants overlap. The inset in the lower left is a diagram (after Imamura, 1937) of a horizontal cross section of a rectangular column, indicating the manner in which horizontal earthquake motion E—E′ causes rotation of the column.

During this study it soon became evident that, to be of value, the direction of rotation must be considered on a statistical basis. Thus, two columns only 10 feet apart in the Christ Church cemetery at Kealakekua were rotated approximately equal amounts in opposite directions. However, by using the prevailing direction of rotation of a number of columns in a single area, more useful results were obtained. The average direction of rotation of monuments in each of six cemetery areas from 5 miles north to 10 miles south of Napoopoo were all consistent with an origin of the earthquake on or near the Kealakekua fault from 2.5 to 5 miles west of Napoopoo.

Cemeteries close to the epicenter showed less consistency in the direction of rotation than did those farther away.

In Figure 12 the prevalent directions of rotation of monuments in four cemeteries are shown. Four other cemeteries were omitted because no monuments were rotated in them, or because the number of rotated monuments was too small to yield a reliable statistical result. At each of the four cemeteries plotted, the boundaries of the octants containing the direction toward the epicenter are prolonged. In an area largely west of the shoreline, from 2 miles south to 2 miles north of the approximate trace of the Kealakekua fault, three or more of the four significant octants overlap, and it is within this area of overlap that the epicenter should be situated.

LOCATION OF THE EPICENTER

Because of the dismantling of all but one of the seismographs on the island of Hawaii during the preliminary phase of the earthquake, it is not possible to locate the origin or epicenter instrumentally. The only instrumental datum available is the S—P interval of 9.5 seconds given by the Bosch-Omori seismograph at the northeast rim of Kilauea Caldera (Fig. 13). Using the travel times given by Byerly (1942: 210), this gives a distance of origin of the earthquake of approximately 47 miles from the Bosch-Omori instrument. These curves were derived for sedimentary and granitic rocks but, over a period of several years of use at the Volcano Observatory, have yielded more satisfactory and reasonable earthquake locations than any others. The use of Jones's (1935: 50) curve for duration of the preliminary waves (T*) increases the distance to only 49 miles. Taking into consideration the area of greatest intensity of the earthquake, these distances place the origin of the quake 3 to 5 miles west of the coastline in the vicinity of Napoopoo. The depth of origin appears probably to have been between 5 and 10 miles.

Some information bearing on the location of the epicenter can be derived from the study of damage by the earthquake. The general distribution of damage to roads, stone walls, and road cuts along the main highway is shown in Figure 3. This is based on a count checked against odometer mileage, assigning one unit of damage for each 1 to 15 feet of collapsed wall or road cut. Despite irregularities, the graph shows a distinctly symmetrical, bell-shaped distribution curve, with its peak about 2.5 miles by road southeast of Captain Cook. An average of more than 60 items of damage per mile in the central 5 miles decreases to only one or two per mile more than 9 miles from the center. This point of maximum damage coincides closely with the position of the buried inland extension of the Kealakekua fault. Other types of damage also were most abundant in the same general area. Together with the fact that most of the aftershocks, located by instrumental means, originated on the Kealakekua fault, it leaves little question that the origin of the major earthquake lay on or close to this fault, and that the earthquake almost certainly resulted from movement on it.

The greatest structural damage was farther south, at Hookena, where the destruction of the east and west walls of the two stone churches suggests an epicenter somewhat farther south. The possibility of a twin earthquake with one epicenter lying offshore nearly west of Hookena has been considered, but no other evidence suggests it, and no signs of a second earthquake could be detected from the seismograms either from the island of Hawaii stations or from that of the Coast and Geodetic Survey at Barbers Point on Oahu.

Throughout the Kona area, the prevalent direction of fall of rock slides, stone walls, and tombstones was westward, and the next commonest direction was eastward. The seismograms indicate that the first movement of the ground was eastward, and it is probable that some of the westward fall of objects was

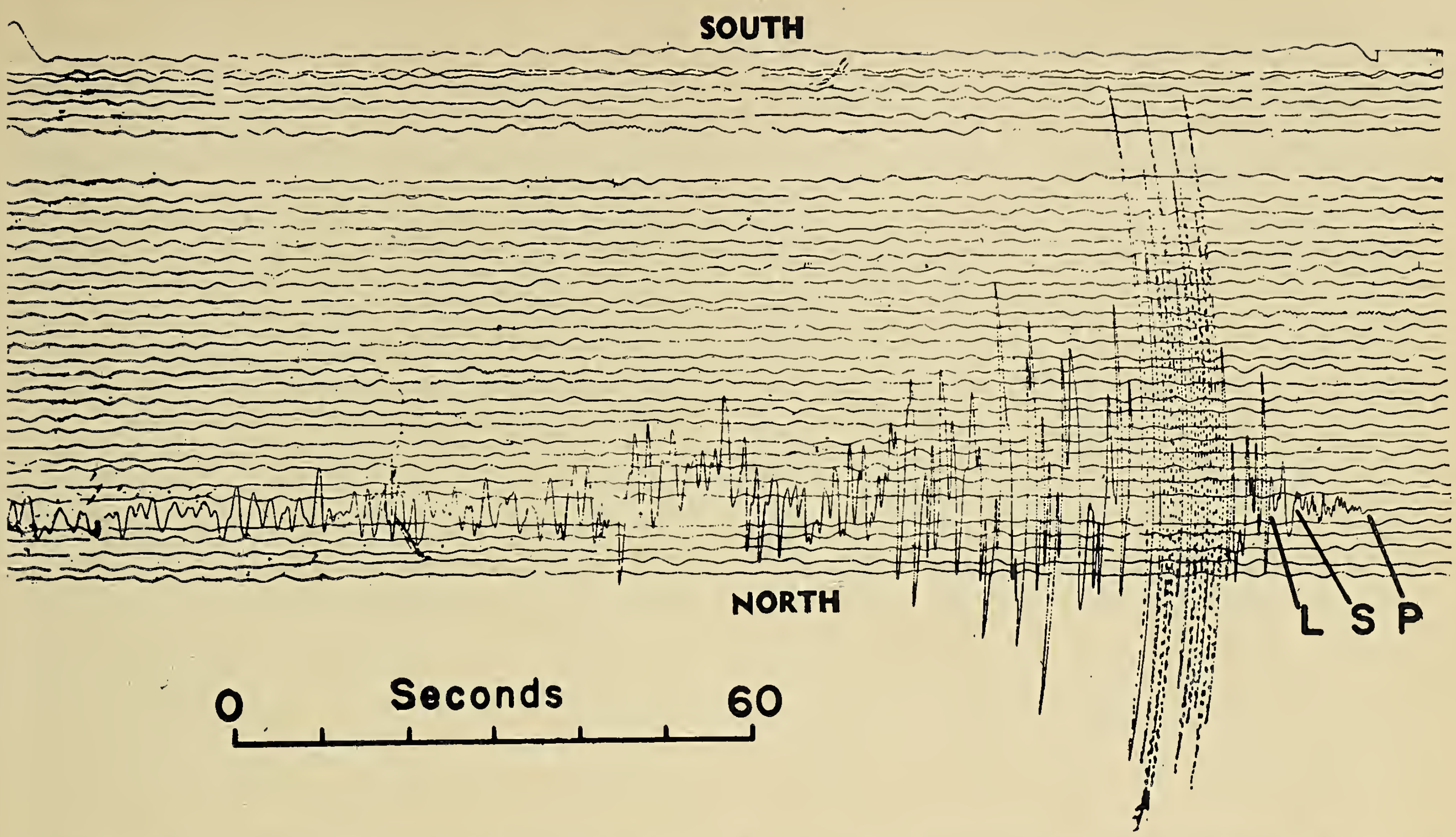

FIG. 13. Seismogram of aftershock recorded at 18:32, August 21, on the Bosch-Omori seismograph at Kilauea. Letters indicate the points of arrival of primary (P), secondary (S), and long (L) waves. The amplitude of 80 mm. on the seismogram corresponds to approximately 0.7 mm. of ground motion at Kilauea, 47 miles from the epicenter.

the result of lagging behind as the ground moved eastward under them. To some extent also, the general east-west azimuth of fall undoubtedly reflects the direction of the epicenter. However, the prevailing east-west slope appears to have been still more important in determining the direction of fall of objects. Its effects on various types of damage have already been indicated.

It has already been pointed out that the prevalent direction of rotation of columns in cemeteries indicates a location of the epicenter within the shaded offshore area in Figure 12. This area contains the seaward extension of the Kealakekua fault.

As a result of the consideration of all lines of evidence, the probable epicenter of the earthquake is placed approximately 3 miles west of Napoopoo, at latitude 19°29′ N, longitude 155°58′ W.

INTENSITY OF THE EARTHQUAKE

There are in common use two different methods of determining and expressing the strength of an earthquake. The older method is based on the observed effects of the earthquake on structures and various other objects. Based on these effects, a numerical value is assigned which is termed the intensity of the earthquake at any one point. Obviously, since the effects are less at greater distances from the origin of the quake, the intensity decreases away from the epicenter. Various scales of intensity have been proposed. That used in the present study is the modified Mercalli intensity scale of 1931 (Wood and Neumann, 1931), in which values range from 1, at which the earthquake is not felt except by a very few persons under especially favorable conditions, to 12, at which damage is total. The second method assigns a value called magnitude to the earthquake, based on the effect on standard seismographs at known distances from the origin of the quake (Richter, 1935). The magnitude is a measure of the amount of energy in the earthquake at its point of origin and, consequently, should be essentially the same at all measuring stations.

The notice of preliminary determination of epicenter issued by the Coast and Geodetic Survey lists the magnitude of the earthquake of August 21 as 6.75 as determined at Pasadena and 7.0 as determined at Berkeley, in California.

Field studies of the effects of the earthquake indicate an intensity of 7 on the modified Mercalli scale in the area near the epicenter, decreasing to 6 at Waiohinu and Naalehu, 5 in the vicinity of Kilauea Caldera and in Hilo, and 4 at Honokaa and in the Kohala district at the north end of the island. At Honolulu, 180 miles (288 km.) from the epicenter, the intensity was 2. Populated areas of the island of Hawaii are largely restricted to the periphery of the island. The interior portions of the island are almost wholly unpopulated, making it impossible to draw accurate isoseismal lines. Approximate isoseismals are shown in Figure 1.

Given a single impulse, the minimum horizontal acceleration that can cause the sliding of a short stone column on a stone base is 71 per cent of the value of gravity, decreasing to 57 per cent at an angle of emergence of 35° to the horizontal (Imamura, 1937: 105). Because the sliding of headstones and, especially, base plates was common in cemeteries during the August 21 earthquake, it might be concluded that the acceleration during the earthquake was at least six tenths that of gravity. However, Imamura (1937: 106) also has shown that small, short-period vibrations in the epicentral areas of strong earthquakes, although they do not themselves cause the displacement of objects, may so lower the normal values of the coefficients of friction that sliding can be caused by longer period vibrations with accelerations much less than six tenths that of gravity. The presence of such vibrations in the Kona area is suggested by local vagaries of displacement and by other behavior. The acceleration which caused the lateral displacement of objects during the Kona earthquake is not known but probably was much less than six tenths that of gravity.

CONCLUSION

The earthquake of August 21, 1951, like most of its aftershocks, probably was caused by movement on the Kealakekua fault. This is one of a number of similar faults along which the lower slopes of Mauna Loa and Kilauea Volcanoes have moved relatively downward and outward toward the deep ocean. In this sense the earthquake was tectonic in origin.

In one sense, of course, all earthquakes in Hawaii are volcanic in origin. However, the August 21 earthquake cannot be directly related to any specific volcanic episode. It is possible that it is related in some way to the great extravasation of lava during the 1950 eruption of Mauna Loa, but there is no evidence to demonstrate such a relationship. On September 16 a series of smaller earthquakes originated on the Kaoiki fault system, a series of fractures corresponding to the Kealakekua fault, on the southeast slope of Mauna Loa. From mid-May until early July abnormally rapid eastward tilting at Kilauea Caldera indicated a tumescence of Mauna Loa Volcano. There is a possibility that both the August 21 earthquake and its aftershocks and the September 16 earthquakes were caused by a slight upward movement of the central portion of Mauna Loa in relation to the lower slopes. The August 21 earthquake has no known connection with any coming volcanic activity, though such a relationship may yet appear.

The southern part of the island of Hawaii is subject to frequent earthquakes, but few are as intense as that of August 21, 1951. The great earthquake of April 2, 1868, judging from the descriptions of damage, was much more severe. Wood (1914) assigned to it an intensity of 10. Its epicenter was farther south, near Waiohinu in Kau, where extensive surface faulting took place. The earthquakes of March 28 and April 3, 1868, also were probably at least as severe as that of August, 1951. The earthquake of October 6, 1929, centered beneath Hualalai Volcano, had a magnitude of 6.5 (Gutenberg and Richter, 1949: 207), and caused damage as far south as Captain Cook. The Maui earthquake on January 23, 1938, had a magnitude of 6.75, about the same as that assigned by the California Institute of Technology Seismological Laboratory in Pasadena for the earthquake of August 21, 1951. During the years from 1929 to 1945, Gutenberg and Richter (1949, table 17) list eight earthquakes of magnitude 5 and over which originated in the general Hawaiian area. During the same interval they list 58 earthquakes in California with magnitude of 5 or more and 127 in Japan and Kamchatka. Thus, during those years, California had about seven times as many large earthquakes as the Hawaiian area, and the Japan-Kamchatka area had about 16 times as many. However, there are some areas, such as the northeastern United States, which have far fewer earthquakes than the Hawaiian area.

Based solely on the 1929–1945 interval, the Hawaiian area can expect an average of about one earthquake of magnitude 5 or more every 2 years. However, during the past century, there have been only six earthquakes of intensity comparable to that of August 21, and no other appears to have been quite as severe in central Kona. There is, of course, no assurance that another equally or even more severe earthquake might not occur in that area in much less time than a century. It might occur within the next few months, but, judging from the past, that is quite unlikely.

Well-built structures, with footings of better quality than many of those now found in Kona, will minimize or even eliminate the damage resulting from the lesser earthquakes which the Kona area experiences frequently in common with all the island of Hawaii except the northernmost part. However, it may not be economically feasible to build in such a way as to eliminate damage from the infrequent large earthquakes.

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The Genus *Acer* (Maples) in Formosa and the Liukiu [Ryukyu] Islands

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THE SPECIES of the genus *Acer* in Formosa and the Liukiu Islands are included in the revisional study of the family Aceraceae made by Fang (1939). The Formosan species are also treated by Kanehira in his work on the Formosan trees (1936). The opinions expressed by these two authors are widely divergent. Fang accepts practically all the species originally described from Formosa, whereas Kanehira reduces a large number to synonymy. Neither of the two treatments is exhaustive, as a few names pertaining to Formosan plants are omitted from each.

For purposes of the present study, the works of these two authors, as well as other pertinent literature, have been critically reviewed. Specimens deposited in the U. S. National Herbarium, Smithsonian Institution, and the herbarium of the National Taiwan University, Formosa, have been studied and are cited, with the abbreviations US and NTU, respectively. In the latter case, only selected specimens are listed. As a result of this study, eight species are recognized for Formosa and one for the Liukiu Islands. The Liukiu entity was formerly considered a variety of a Chinese species, but it is here raised to specific rank. Two new varieties are proposed herein, and several new synonyms are noted.

KEY TO THE SPECIES IN FORMOSA AND LIUKIU ISLANDS

A. Leaves entire.
  B. Leaves undivided, rarely indistinctly 3-lobed.
    C. Leaves glaucous beneath.
      D. Leaves obtuse or cuneate at base, not 3-nerved. 1. *A. albopurpurascens*
      DD. Leaves rounded to cordate and distinctly 3-nerved at base.................... 2. *A. itoanum*
    CC. Leaves white-pubescent beneath.................... 3. *A. hypoleucum*
  BB. Leaves 3-lobed.................... 4. *A. buergerianum* var. *formosanum*
AA. Leaves serrate.
  B. Leaves undivided to shallowly 3- or rarely 5-lobed.
    C. Leaves mostly undivided, sometimes shallowly 3- or rarely 5-lobed; inflorescence racemose.
      D. Fruit 2–2.2 cm. long.................... 5. *A. kawakamii*
      DD. Fruit 2.5–3 cm. long.......... 5a. *A. kawakamii* var. *taitonmontanum*
    CC. Leaves distinctly 3–5-lobed; inflorescence cymose.................... 6. *A. tutcheri* var. *shimadai*
  BB. Leaves distinctly 5- or 7-lobed.
    C. Leaves all 5-lobed.
      D. Leaves shallowly 5-lobed; fruit 1.8–2.3 cm. long....... 7. *A. rubescens*
      DD. Leaves deeply 5-lobed; fruit 2.5 cm. long....... 8. *A. serrulatum*
    CC. Leaves all 7-lobed.................... 9. *A. palmatum* var. *pubescens*

1. **Acer albopurpurascens** Hay. (1911: 64).

Acer litseaefolium Hay. (1913: 66, pl. 14, b).
Acer oblongum sensu Matsum. & Hay. (1906: 96); Koidz. (1911*b*: 55), p. p.;

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Kanehira (1936: 506, fig. 361) [non Wall.].

Acer lanceolatum sensu Rehder (1905: 180) p. p. [non Molliard].

An evergreen tree to 15 cm. high; branchlets pubescent at first, soon glabrous. Leaves persistent, coriaceous, oblong-lanceolate, 6–13 cm. long, 2.5–5 cm. broad, caudate to acuminate at apex, obtuse to cuneate at base, pale green and glabrous above, white-purplish-glaucous beneath, densely pubescent when young, weakly 3-nerved at base, the basal nerves short, slightly raised or indistinct, the lateral nerves 7–10 per side, slightly raised, divergent at right angles; petioles 1.5–3 cm. long, glaucous. Infructescence cymose; nutlets glabrous, about 3 mm. across; wings with nutlets about 2 mm. long, spreading at obtuse angles.

Endemic to Formosa; in forests from medium to low altitudes throughout the island.

Formosa: South Cape, *A. Henry 1257* (US); Musha, Nanto Prov., *E. H. Wilson 10082* (US); Kizan-gun, Takao-syu, *Y. Yamamoto & K. Mori 808* (NTU).

The concept of *A. oblongum* Wall. in eastern Asia has been considerably modified in recent years. The species is now considered as occurring only in northeastern India and western China, and other plants of this immediate relationship from eastern and southern China are considered to represent distinct species by recent authors, perhaps too many such species being recognized. Hayata earlier established three species of this group in Formosa, namely *A. albopurpurascens*, *A. litseaefolium*, and *A. hypoleucum*, but later workers on the Formosan flora, including Kanehira (1936) and Sasaki (1930: 325), consider them as a single species, to which they refer as *A. oblongum* Wall. Metcalf (1932: 198) and Fang (1939: 145–163) maintain all three as distinct. The Formosan plant, under the current concept, should be specifically distinguished from *A. oblongum* especially because of the weak or indistinct basal nerves. But probably only one species is present on the island; the identity of *A. hypoleucum* is somewhat uncertain.

A plant from the Liukiu Islands, considered as a variety of *A. oblongum*, has distinct morphological characters and an outlying range. It should be treated as a separate species.

2. *Acer itoanum* (Hay.) comb. nov.

Acer oblongum Wall. var. *itoanum* Hay. (1911: 67); Metcalf (1932: 196); Fang (1939: 138).

Acer oblongum var. *microcarpum* sensu Ito ex Ito & Matsum. (1898: 387) [non Hieronymus].

Acer oblongum sensu Koidz. (1911*b*: 55, pl. 29) p. p.

Tree to 13 m.; branchlets glabrous, the young ones reddish, the older grayish. Leaves thin-coriaceous, glabrous, ovate to broadly ovate, 4.5–6.5 cm. long, 2–4.5 cm. broad, abruptly acuminate at apex, rounded to cordate at base, entire at margins, usually undivided, rarely indistinctly and obtusely 3-lobed, green above, glaucous beneath, distinctly 3-nerved at base, the veins distinct on both surfaces, the basal nerves long and strongly ascending, the lateral nerves 3–5 per side, the veinlets densely reticulate, elevated and distinct on both surfaces; petioles slender, to 2.5 cm. long, glabrous. Flowers unknown. Infructescence terminal, corymbose, pubescent; peduncles about 1 cm. long; pedicels to 1 cm. long, slender, pubescent. Fruit brownish yellow; nutlets convex, 5–6 mm. long, 3–4 mm. broad; wings oblong, with nutlets about 1.5–2 cm. long, 5 mm. broad, spreading at about 45–90°.

Endemic to the Liukiu Islands.

Liukiu Islands: Okinawa, *W. D. Field & O. G. Loew 4* (US); Shuri, *E. H. Wilson 8172* (US), *C. Wright 40* (US).

This species differs from *A. oblongum* Wall. in the small, short, ovate leaves, which are abruptly acuminate at apex and distinctly rounded to cordate at base, as well as in the smaller fruits with pubescent pedicels. The wings of the fruit are oblong rather than ovate in shape. Among the specimens cited, *Field & Loew 4* has the leaves mostly broader and more distinctly cordate, with a few having a tendency toward being indistinctly 3-lobed. The illustration given by Koidzumi, showing leaves with round to cordate bases, evidently refers to the Liukiu plant.

3. **Acer hypoleucum** Hay. (1913: 66, pl. 14, c).

Small tree; branchlets slender, tomentose at first, soon glaucous. Leaves persistent, chartaceous to coriaceous, oblong or elliptic-oblong, about 8 cm. long, 3.5–4 cm. broad, obtuse or acutish at apex, rounded or obtuse at base, entire or slightly undulate at margins, green above, whitish-glaucescent and densely tomentose beneath, slightly 3-nerved at base, the nerves raised and more or less distinct, the lateral nerves 5 or 6 per side; petioles 2–3 cm. long, slender, tomentose. Infructescence cymose, terminal; nutlets convex, about 5 mm. across; wings with nutlets about 17 mm. long and 6 mm. broad, spreading at nearly right angles; pedicels 1.5 cm. long, slender, pubescent.

Endemic to Formosa; no specimen seen.

Acer hypoleucum is described as being pubescent on the lower surface of the leaves. It is thus maintained as distinct from *A. albopurpurascens* by Metcalf and Fang; the latter has seen the type. However, Kanehira relegates it, together with *A. albopurpurascens*, to the synonymy of *A. oblongum* (sensu Kanehira non Wall.). In *A. albopurpurascens*, the young leaves are densely pubescent, as shown in *Wilson 10082*. The presence or absence of these hairs may be due to variation in age and environment. Further studies are needed to ascertain the identity of *A. hypoleucum*.

4. **Acer buergerianum** Miquel var. **formosanum** (Hay.) Sasaki (1928: 275); Fang (1939: 128).

Acer trifidum Hook. & Arn. var. *formosanum* Hay. ex Léveillé (1906: 593); Koidz. (1911*b*: 30, pl. 17, 8–9); Kanehira (1936: 409, fig. 364).

Tree to 10 m. high; branchlets glabrescent. Leaves deciduous, membranaceous, ovate to elliptic, 8–10 cm. long, 4–6 cm. broad, rounded or slightly cordate at base, entire or shallowly 3-lobed near apex, 3-nerved at base, the reticulations conspicuous; petioles 2.5–5 cm. long. Inflorescence corymbose. Fruits yellowish brown; nutlets strongly convex, about 6 mm. across; wings falcate, with nutlets 2.5–3 cm. long, 8–10 mm. broad, spreading horizontally.

Formosa: Huki-kaku, *T. Kawakami*, May 1915 (NTU).

The species occurs in southeastern China, the variety is endemic to the coast of northern Formosa, in forests. Fang maintains the variety on the basis of the type specimen, which he examined.

5. **Acer kawakamii** Koidz. (1911*a*: [102] [March]; 1911*b*: 15, pl. 5 [Aug.]); Kanehira (1936: 402, fig. 360).

Acer caudatifolium Hay. (1911: 65 [June]).
Acer morrisonense Hay. (1911: 66, ex Koidz. 1911*a*: 16, pl. 7).
Acer ovatifolium Koidz. (1911*a*: [102]); (1911*b*: 16, pl. 6).
Acer caudatum sensu Matsum. & Hay. (1906: 96) [non Wall.].

A tree to 20 m. high; branchlets slender, glabrous. Leaves deciduous, chartaceous, ovate to ovate-oblong, 6–10 cm. long, 3–5 cm. broad, caudate-acuminate at apex, rounded or slightly cordate at base, serrate and sometimes shallowly 3- or rarely 5-lobed at margins, 5-nerved at base, the lateral nerves 7 or 8 per side, green above, pale green beneath, slightly pubescent on nerves at first, soon glabrous; petioles 3–4 cm. long, rosy, slender, glabrous. Flowers in glabrous or slightly pubescent racemes about 5 cm. long; sepals 5, emarginate, 2–2.5 mm. long; petals 5, white, emarginate, 3.5–4 mm. long; stamens 8, shorter than the sepals; ovary glabrous; pedicels 5–6 mm. long, slender, glabrous. Fruit yellowish brown; nutlets about 5 mm. across; wings falcate, with nutlets 2–2.2 cm. long, 8–12 mm. broad, spreading at obtuse angles; pedicels 6–7 mm. long.

Endemic to Formosa, in forests of high mountains in the central range, from 2,000 to 2,500 meters.

Formosa: Mt. Taipinshan, *H. Keng 1224* (NTU, US); Arisan, *E. H. Wilson 9643* (US), *10830* (US).

Fang (*loc. cit.*) maintains *A. morrisonense* and *A. taiton-montanum* as distinct species, but Kanehira reduces both to the synonymy of *A. kawakamii. A. taiton-montanum* is here treated as representing a variety of the latter species. *A. ovatifolium* Koidz. is suggested by Fang (1939: 181) as "probably identical with *Acer kawakamii* Koidzumi," and I think this is where it should be referred. As undivided and lobed leaves are often found on the same plant, this character alone is apparently not constant enough for specific distinction.

5a. ***Acer kawakamii*** Koidz. var. ***taitonmontanum*** (Hay.) comb. nov.

Acer taiton-montanum Hay. (1913: 67).

Leaves chartaceous, triangular-ovate, 5–7 cm. long, 4–5 cm. broad, the margins doubly serrate, undivided or shallowly 3- or 5-lobed. Fruiting racemes to 4 cm. long; nutlets slightly concave, about 1 cm. long and 5 mm. broad; wings with nutlets 2.5–3 cm. long, about 8 mm. broad, spreading at right angles; pedicels 6–7 cm. long, glabrous.

Endemic to Taiton Mountains, northern Formosa, near sulfur hot springs at about 650 meters altitude.

Formosa: Sozan, Taihoku-syu, *T. Tanaka & Y. Shimada 11006* (US), *E. H. Wilson 11229* (US), *N. Fukuyama 8010* (NTU).

Acer taiton-montanum is treated as a synonym of *A. kawakamii* by Kanehira and as a distinct species by Fang. It is very close to *A. kawakamii*, differing only in the larger fruit. The leaves also vary from undivided to 3- or rarely 5-lobed. The typical variety of *A. kawakamii* occurs in the high central mountains from 2,000 to 3,000 meters, whereas this variety is confined to the Taiton Mountains in northern Formosa at an altitude of about 650 meters, near sulfur hot springs. This is an interesting case of ecological differentiation. There are similar examples in other plants occurring in these two localities.

6. **Acer tutcheri** Duthie var. **shamadai** Hay. (1911: 70); Kanehira (1936: 405).

Acer oliverianum subvar. *trilobatum* Koidz. (1911*b*: 34, fig. 2).

A deciduous tree. Leaves broadly rhomboid, about 15 cm. long and 7 cm. broad, 3-lobed, rounded at base, distinctly 3-nerved, serrulate at margins, subentire toward base, the lobes similar in size or the basal ones slightly smaller, the terminal lobe broadly triangular, about 2.5 cm. long and 3 cm. broad; petioles about 4 cm. long. Infructescence cymose, terminal, about 6 cm. broad and 7 cm. long including the peduncles of 2–3 cm.; fruit glabrous, the nutlets ovoid, about 4.5 mm. long; wings with nutlets about 1.5 cm. long and 6 mm. broad, divaricate at about 40°.

Endemic to Formosa, central mountains, in forests. No specimen seen.

The typical variety of *A. tutcheri* is confined to Kwangtung and Kwangsi. The Formosan plant, as described by Hayata, appears to be very close to it except in the smaller fruit and much less divaricate wings. This variety is not treated in Fang's revision.

7. **Acer rubescens** Hay. (1911: 66); Koidz. (1911*b*: 21, pl. 11); Kanehira (1936: 405, fig. 363).

A deciduous tree, 10–20 m. high; branchlets glabrous. Leaves chartaceous, roundish-ovate in outline, 6–10 cm. long, 5–8 cm. broad, truncate or subcordate and 5-nerved at base (lateral nerves 5 or 6 per side), doubly serrate at margins, green above, glabrous beneath, shallowly 5-lobed, the middle lobe shortly ovate, acuminate or caudate-acuminate at apex, the lateral lobes smaller, acute to obtusish at apex; petioles 5–7 cm. long. Fruits yellowish brown, small, racemose; nutlets subellipsoidal, about 6 mm. long and 4 mm. broad; wings with nutlets 1.8–2.3 cm. long, 6–7 mm. broad, divaricate at 90–110°; pedicels 7–10 mm. long, slender, glabrous.

Endemic to Formosa, in forests at high altitudes of 1,800–2,200 meters, central ranges.

Formosa: Mt. Taihei, Taihoku-syu, *S. Suzuki 247* (NTU); New Paisienshan, *H. Keng*, Nov. 5, 1950 (NTU, US).

8. **Acer serrulatum** Hay. (1911: 70).

Acer oliverianum Pax var. *nakaharai* Hay. (1911: 68); Koidz. (1911*b*: 33, pl. 20); Kanehira (1936: 405, fig. 362).

Acer oliverianum Pax var. *nakaharai* Hay. f. *longistaminum* Hay. (1911: 69).

Acer oliverianum Pax var. *microcarpum* Hay. (1911: 69).

Acer oliverianum Pax var. *nakaharai* subvar. *formosanum* Koidz. (1911*b*: 33, fig. 1).

A tree up to 20 m. high; branchlets reddish, glabrous. Leaves rounded-cordate to broadly orbicular, about 7–7.5 cm. long and 9–10 cm. broad, glabrous on both surfaces, cordate at base, the nerves about 5 per side, the veinlets finely reticulate, distinct on both surfaces, palmately 5-lobed, the lobes more or less equal or the lower smaller, triangular-lanceolate to triangular-ovate, irregularly or duplicately crenate-serrate, the terminal lobe about 5–7.5 cm. long and 1.5–2 cm. broad; petioles 2–2.5 cm. long, glabrous. Flowers in terminal cymose inflorescences; peduncles 3–5 cm. long, glabrous; pedicels to 6 mm. long; sepals 5, rounded-oblong, 2 mm. long, hirsute toward the apex on both surfaces, the margins tomentose-ciliate; petals 5, yellow, rounded, 1.25 mm. long, obscurely denticulate to subentire at margins; stamens 5–7, the filaments 1 mm. long, the anthers oblong, 1 mm. long; ovary 0.6 mm. long, hirsute; styles 2, connate, about 2 mm. long; disc thick, 5–7-lobed, the lobes rounded. Nutlets ellipsoid-oblong, about 14 mm. long; wings obovate, with nutlets 2.5 cm. long, divaricate at 90–120°.

Endemic to Formosa, common in forests at altitudes of 1,000–2,000 meters throughout the island.

Formosa: Sozan, *E. H. Wilson 10786* (US); Taihoku, *E. H. Wilson 10129* (US); Mt. Morrison, *H. H. Bartlett 6297* (US); Bunzan-gun, Taihoku-syu, *T. Suzuki 18390* (NTU); between Pianan and Sikayo, *G. Masamune 1082* (NTU), Kiriyama and Tiponzae, *S. Suzuki 11019* (NTU).

This species is the largest tree of the genus on the island, widely distributed and very common in forests at altitudes of about 1,000–2,000 meters. Although some variations in the leaves are found, the plants from different localities clearly represent a single species. Kanehira's combination of *A. serrulatum* and *A. oliverianum* var. *nakaharai* is thus followed. The type of *A. serrulatum* is a sterile specimen, and for this reason, Fang (1939: 87), who has examined the type, could not ascertain the identity of the species. Earlier, however, Koidzumi, who also had access to the type, had already listed Hayata's name in the synonymy of *A. oliverianum* var. *nakaharai* Hay.

This species is here considered as distinct from *A. oliverianum* of western China. It differs from the latter in the more deeply serrate leaves, with crenate instead of sharply appressed serrations. The sepals are densely hirsute and the stamens are shorter than in *A. oliverianum*. Furthermore, *A. serrulatum* has the fruit-wings divaricate at about 120°, whereas in *A. oliverianum* the fruit-wings are spreading horizontally.

In *A. oliverianum*, Koidzumi described another subvariety, *A. oliverianum* var. *nakaharai* subvar. *trilobum* Koidz., with 3-lobed leaves. This, as noted above, is now known as *A.*

tutcheri Duthie var. *shimadai* Hay. Another variety with 3-lobed leaves, described from the neighboring province Fukien, should be considered as a distinct species: *A. johnedwardianum* Metcalf (1942: 221). (*A. wilsonii* Rehder var. *serrulatum* Dunn in Linn. Soc. London, Jour., Bot. 38: 358, 1908; *A. oliverianum* Pax var. *serrulatum* (Dunn) Rehder in Sarg., Pl. Wils. 1: 90, 1911; non *A. serrulatum* Hay.). *A. oliverianum* occurs from eastern to southwestern China, while *A. johnedwardianum* is localized in Fukien. It differs from the former in the 3-lobed leaves, which are glabrous and rounded at base, and in the smaller fruits, which are arranged in a slender corymb.

9. ***Acer palmatum*** Thunb. var. ***pubescens*** var. nov.

Acer duplicato-serrulatum Hay. (1911: 70).
Acer palmatum Thunb. subsp. *matsumurae* Koidz. var. *spontaneum* Koidz. subvar. *formosanum* Koidz. (1911*b*: 50).
Acer ornatum Carr. var. *matsumurae* Koidz. α. *spontaneum* (Koidz.) Nemoto subvar. *formosanum* (Koidz.) Nemoto (1936: 454).
Acer matsumurae Koidz. var. *formosanum* Sasaki (1930: 324) [nomen nudum].

A typo speciei differt ramulis novellis, foliis utrinque, petiolis, inflorescentiisque molliter pubescentibus.

A small tree, young branchlets slender, white-villose-pubescent, becoming glabrescent and glabrous. Leaves to 5 cm. long, subcordate, deeply 5-lobed, the base cordate, the lobes lance-oblong, acuminate, subduplicately serrate, villose especially on the veins on both surfaces, the lobes parted to beyond the middle; petioles glabrous, slender, 2.5 cm. long, villose-pubescent. Inflorescence in small corymbs, densely villose-pubescent at first; peduncles 1–2.5 cm. long; pedicels 5–6 mm. long; sepals slightly purplish, ovate-oblong, 2–3 mm. long, more or less glabrous; petals slightly smaller than the sepals, white; stamens short, included, the filaments about 1 mm. long, the anthers about equal in length; ovary densely villose.

Endemic to mountain forests at altitudes of about 1,600 meters, central and northern parts.

Formosa: Taranan, Bunzan-gun, Taihoku-syu, *T. Suzuki 17859* (NTU, type); Mt. Taihei, *S. Sasaki*, Sept. 2, 1925 (NTU).

The nomenclature of cultivated and wild forms of *A. palmatum* Thunb., as adopted by several Japanese botanists, is very varied and confusing. The wild plant growing spontaneously in the mountains of Formosa differs from the Japanese plants chiefly in the pubescence being present not only on the young branches and inflorescences, but also on mature leaves and petioles. As it is geographically isolated from other plants of this species, it is here considered as a distinct variety.

Acer duplicato-serrulatum Hay. is listed as a synonym of *A. oliverianum* var. *nakaharai* = *A. serrulatum* by Kanehira. This is evidently incorrect, as the former has 7-lobed leaves, while the latter has 5-lobed leaves. This name is not taken up by Fang. However, Koidzumi, who had access to Hayata's type, earlier identified this with the wild form of *A. palmatum* from Formosa. The type, as noted by Koidzumi, is a sterile specimen.

Acer matsumurae Koidz. var. *formosanum* Sasaki was published without description or reference, hence is a nomen nudum and invalid.

EXCLUDED SPECIES

Acer taiwanense Yamamoto, Soc. Trop. Agr., Jour. [Formosa] 5: 180, fig. 6, 1933.

This name, not listed by Kanehira but by S. Suzuki (1936: 129), is, as noted by Fang (1939: 246), actually based upon a specimen collected in Cochin-China. It should be eliminated from the list of plants of Formosa.

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A New Species of Amphipod from Lower California (Genus *Eriopisa*)[1]

J. LAURENS BARNARD[2]

AMONG RECENT COLLECTIONS of amphipods made by Dr. John S. Garth along the coast of Lower California, from the research vessel "Velero IV," were those reported upon here, a new species belonging to the genus *Eriopisa* Stebbing (1890: 193). I am pleased to name this amphipod for Dr. Garth, in whose laboratory the work was carried out, and whose counsel for several years has been greatly appreciated. I am also indebted to Captain Allan Hancock, Director, and Dr. James W. Buchanan, Director of Research, Allan Hancock Foundation, for support and equipment.

Eriopisa garthi new species

Figs. 1, 2

DESCRIPTION OF MALE.—Head nearly as long as first 2 body segments, lateral lobes strongly produced, obtuse. Eyes not visible.

Antenna 1 about as long as head and peraeon combined, articles 1 and 2 of peduncle subequal in length, article 3 about half as long as article 2. Flagellum slender, 1.5 times as long as peduncle, with as many as 16 articles. Accessory flagellum with 2 articles, longer than first article of primary flagellum.

Antenna 2 reaching slightly beyond end of peduncle of antenna 1, articles 4 and 5 equal in length, flagellum slightly longer than article 5 of peduncle.

Mandible: Molar conical, primary plate with 4–5 teeth, accessory plate with 4 teeth, spine row with 5 simple spines. Palp article 3 two thirds as long as article 2.

Lower lip: Inner and outer lobes well developed, apices rounded, mandibular lobes short.

Maxilla 1: Inner plate with 3 long setae and 2 small, medial setae, outer plate with 9 spines; apex of palp article 2 with an acute tooth, 3 spines and 2 setae.

Maxilla 2: Inner plate broader than outer, inner edge lined with several strong setae.

Maxilliped: Inner plate subrectangular, apex truncate, but with rough indentations, armed with 3 spines and several setae; outer plate reaching to middle of palp article 2, strongly armed with setae. Palp article 4 slender, conical, curved, about as long as article 3.

Gnathopod 1: Coxa not triangular, inferoanterior edge rounded; article 2 rather stout; article 4 large, posterior surface echinulate; article 5 slightly longer than 4, attached along the anterior surface of the latter; article 6 longer than 5, palm oblique, convex, lined with setules, defined by a spine; article 7 slender, curved, longer than palm.

Gnathopod 2: Articles 4 and 5 short; article 5 produced into a posterior setose lobe; article 6 very large, elongate, palm with a large, subacute medial tooth bearing spinules, posterior to which the palm is hemispherically excavated; the posterior wing of the excavation bearing 3 spines; article 7 strong, curved, fitting palm.

Peraeopod 1 slightly larger than 2, slender, articles 4 and 5 equal in length, shorter than article 6; article 7 slightly curved.

Peraeopod 3 shorter than 1, coxa produced

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[2] Research Fellow, Allan Hancock Foundation.

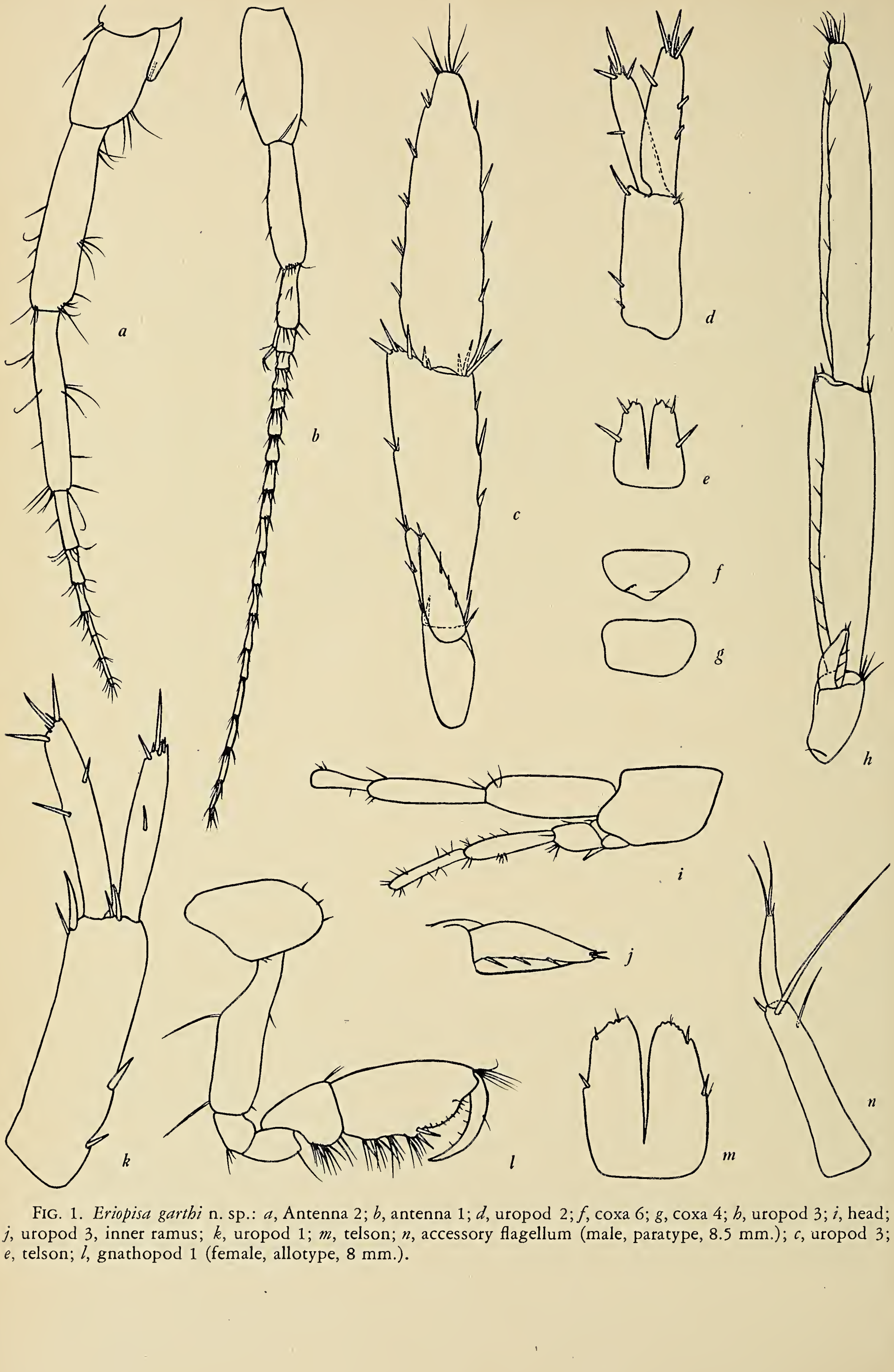

FIG. 1. *Eriopisa garthi* n. sp.: *a*, Antenna 2; *b*, antenna 1; *d*, uropod 2; *f*, coxa 6; *g*, coxa 4; *h*, uropod 3; *i*, head; *j*, uropod 3, inner ramus; *k*, uropod 1; *m*, telson; *n*, accessory flagellum (male, paratype, 8.5 mm.); *c*, uropod 3; *e*, telson; *l*, gnathopod 1 (female, allotype, 8 mm.).

downward anteriorly into a rounded lobe, article 2 not broadly expanded, posterodistal corner produced downward into a rounded lobe; articles 5 and 6 equal in length, longer than 4.

Peraeopods 4 and 5 successively longer, peraeopod 4 intermediate in size between 3 and 5, peraeopod 5 greatly elongated; coxae triangular in shape, not lobed; posterodistal corner of article 2 produced downward into a subacute lobe, articles 4–6 successively longger; article 4 about as long as 2.

Pleopods: outer ramus shorter than inner, both elongated, longer than peduncle, each with 9 articles.

Uropods 1 and 2 short, not reaching much beyond last urosome segment. Uropod 1 reaching to end of uropod 2, inner ramus nearly as long as peduncle, outer ramus shorter than inner.

Uropod 2: Inner ramus subequal in length to peduncle, longer than outer ramus.

Uropod 3 greatly elongated, nearly one half the length of the body. Peduncle very short; inner ramus shorter than peduncle, conical, tipped with 2 spinules; outer ramus very long, more than 5 times as long as peduncle, composed of 2 flattened articles slightly curved upward at the edges, the distal article slightly longer than the proximal one, rounded distally and apically setose.

Telson split, lobes broad, apices oblique, serrate, each lobe armed with 2 spines and a setule.

Body very slender, none of the segments dorsally carinate or toothed.

Pleon segment 3: Lower posterior corner produced into an acute tooth.

FEMALE.—Differing from the male by the small second gnathopods, article 6 of which resembles gnathopod 1; and by the shorter and broader third uropods on which the inner ramus is about one half the length of the proximal article of the outer ramus. Apices of telson more acute (possibly due to the juvenility of the females available, as young males show this same characteristic).

TYPES.—Holotype, Allan Hancock Foundation No. 513, male, 7.2 mm.; paratype, 8.5 mm. (figured); allotype, female, 5 mm. (figured).

TYPE LOCALITY.—"Velero" Station 2066–51, Punta Eugenia, Lower California, Mexico, November 1, 1951, intertidal, under rock on gravel.

MATERIAL EXAMINED.—The types and 12 other specimens from the type locality.

REMARKS.—Four species belonging to the genus *Eriopisa* were previously known. These are *Eriopisa elongata* (Bruzelius, 1859), *E. philippensis* (Chilton, 1920), *E. chilkensis* (Chilton, 1921), and *E. seurati* Gauthier (1936). They are characterized generally by the following characters: (1) Inner edge of inner plate on maxilla 1 strongly setose; (2) setae present on inner edge of inner plate of maxilla 2; (3) lower anterior edge of coxa 1 not greatly prolonged; (4) mandibular palp with setae well developed on article 3 and several on article 2, palp well developed structurally; (5) gnathopod 2 much larger than 1. The new species treated here agrees in concept with items 2–5 but not with item 1, as the present material has only 3 well-developed setae on the inner edge of the inner plate of maxilla 1, a characteristic of the closely related genus *Eriopisella* Chevreux (1920). The latter was separated from *Eriopisa* by the paucity of setae on the inner plates of the first two maxillae.

The known species of the genus *Eriopisella* are *E. pusilla* Chevreux (1920), *E. capensis* (K. H. Barnard, 1916), and *E. sechellensis* (Chevreux, 1901). The present species is separated from these by the presence of setae on the inner edge of the inner plate of maxilla 2, by the rounded first coxal plate, by the armature and stoutness of the mandibular palp, by the large size of the distal article of the outer ramus of uropod 3, and by the diversity in size of the first 2 pairs of gnathopods.

Although transgressing the defining characters of the genera *Eriopisa* and *Eriopisella*

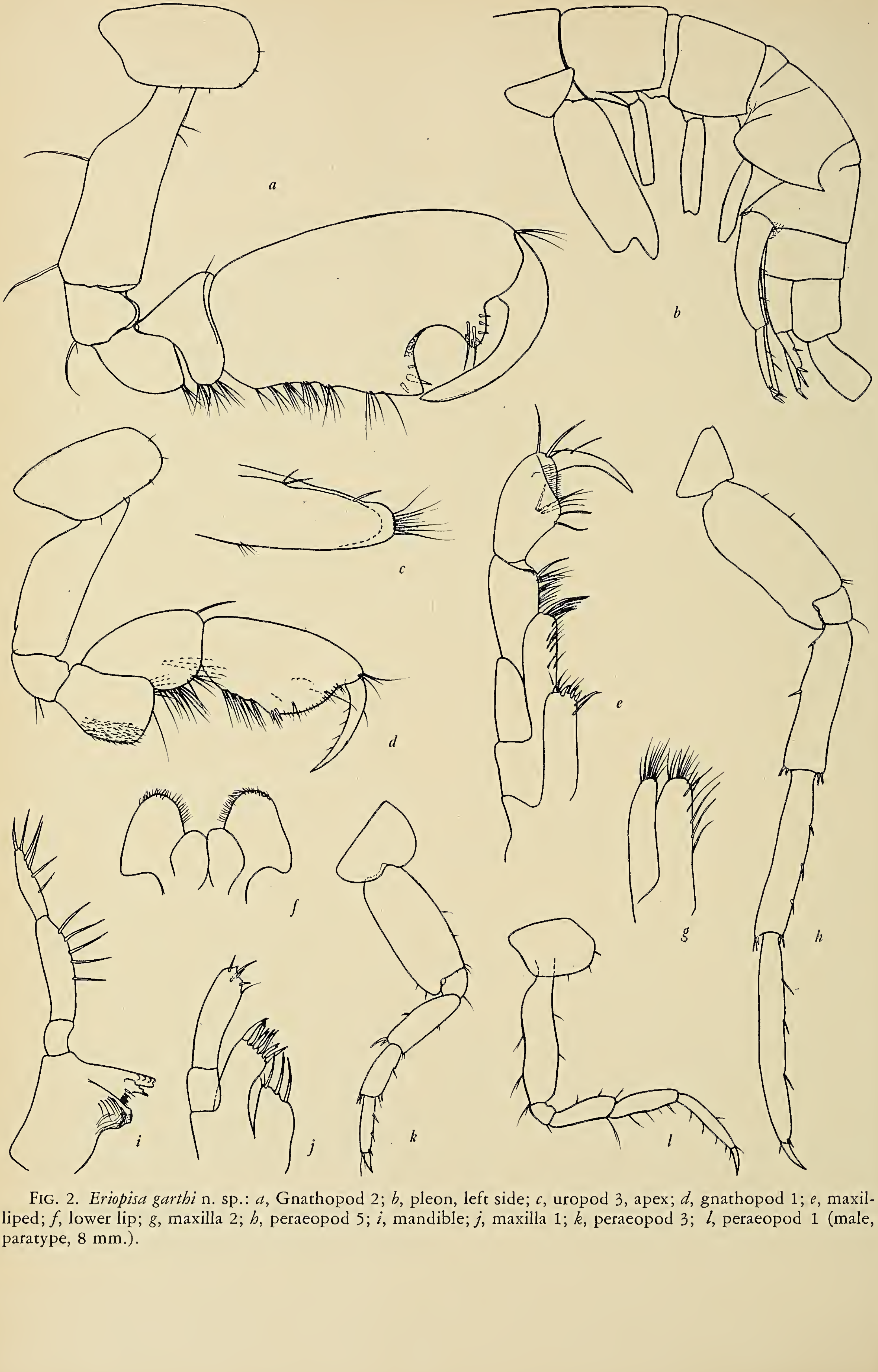

FIG. 2. *Eriopisa garthi* n. sp.: *a*, Gnathopod 2; *b*, pleon, left side; *c*, uropod 3, apex; *d*, gnathopod 1; *e*, maxilliped; *f*, lower lip; *g*, maxilla 2; *h*, peraeopod 5; *i*, mandible; *j*, maxilla 1; *k*, peraeopod 3; *l*, peraeopod 1 (male, paratype, 8 mm.).

as stated by Chevreux (1920), with regard to the lack of setae on maxilla 1, the new species fits into the genus *Eriopisa* on the basis of characters 2–5 as stated above. It differs from the known species in the genus not only by the character of maxilla 1, inner plate, but also by the character of article 6 of gnathopod 2, wherein the palm is deeply excavated.

This is the first record of the genus *Eriopisa* on the Pacific Coast of North America.

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The Nassariidae of the West Coast of North America between Cape San Lucas, Lower California, and Cape Flattery, Washington

JOAN DEMOND[1]

THE MOLLUSCS which constitute the family Nassariidae are worldwide in distribution and include several hundred species. The family has long been, and still is, in need of complete taxonomic revision. However, such a revision is beyond the scope of this paper, which is arbitrarily limited to a consideration of those species of Nassariidae found living on the west coast of North America within the area between Cape San Lucas, Lower California, and Cape Flattery, Washington.

A summary of the known ecology of these molluscs was thought valuable since the literature on this subject is scattered and difficult of access. To the author's knowledge, no such compilation has previously been attempted.

As far as possible, detailed synonymies, shell descriptions, distributional records, and habitat remarks have been compiled for each of the 12 species and two subspecies found in this area. Revisions of the west coast faunal list are suggested. A key based entirely upon external shell characteristics of adult specimens is presented. Illustrations of all west coast species are included.

In making this study, collections were examined at the California Academy of Sciences in San Francisco, at Stanford University, and at both the Los Angeles and Berkeley campuses of the University of California. Reference was also made to remnants of the Josiah Keep Collection at Mills College. In addition, specimens were collected at several west coast localities.

I wish to thank Dr. Leo George Hertlein, California Academy of Sciences, for making the collection of that institution available to me, for his hours of assistance, and for his suggestions. I am particularly indebted to Dr. William M. Ingram, Mills College, who inspired and guided the entire project.

My sincere thanks are also extended to the following individuals: Dr. W. A. Hilton, Pomona College; Dr. Willis P. Popenoe and Dr. Ulysses S. Grant, University of California at Los Angeles; Dr. Howard Hill, Curator of Zoology, Los Angeles County Museum; Dr. A. Myra Keen, Stanford University; Frank R. Rogers, Photographer, and Veronica Sexton, Librarian, California Academy of Sciences.

ECOLOGY OF THE NASSARIIDAE

Habitat

The Nassariidae are distributed throughout the marine waters of the world; the only portions of the globe where they have not been found is in the icy seas near the poles. However, they occur principally in tropical and subtropical waters. Most of the species are littoral, although a few live at considerable depths.

These gastropods are called mud snails, since many aggregate on mud flats and in the shallow water of bays and inlets. For example, I have collected *Nassarius tegula* in great numbers from the mud flats at Estero de Punta Banda, Lower California, and in lesser numbers from the flats of Anaheim and Alamitos

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bays, Southern California. I have taken *N. fossatus* from the flats at Anaheim Bay and MacGinitie (1935) reports this species from the flats at Elkhorn Slough, California. During low tide at Bay Farm Island, San Francisco Bay, I have seen the mud dotted with hundreds of *N. obsoletus.*

Behavior

The Nassariidae are active molluscs. They burrow readily, leaving a small mound of dirt which discloses their location. By means of their large, muscular foot, they plow through the mud, usually in search of food, the bifurcated foot leaving a characteristic trail behind.

Since most Nassariidae are burrowers, they avoid desiccation and can often escape from predators. Also, this burrowing habit, as well as the habit of living in sheltered bays, isolates these gastropods from the destructive action of waves and currents.

There is disagreement regarding the actions of the Nassariidae when left exposed by the tide's recession, or perhaps some species react in an opposite manner from others. Tryon (1882) says that, when the tide goes out, *N. reticulatus* buries itself in the sand to await the water's return. MacGinitie (1935) also states that the Nassariidae burrow when exposed. However, according to Rogers (1939), when the tide recedes, *N. trivittatus* comes up from beneath the sand and crawls toward the water.

Food and Feeding

Because the Nassariidae are carnivorous, they are pests to oyster growers. They bore into oyster shells, insert their extensible proboscis, and eat out the contents. An adult *Nassarius* bores through a 3-year-old oyster shell in 8 hours, but the younger gastropods are far more destructive, selecting the delicate shells of the very young oysters and piercing 15 or 20 in rapid succession. A month-old oyster is eaten in half an hour.

These snails also bore through shells of other pelecypods and gastropods, devouring the soft parts. At Estero de Punta Banda, I have seen live specimens of the large Bubble Shell, *Bullaria gouldiana*, covered with hungry *Nassarius tegula* apparently enjoying a fresh meal at the expense of their ill-fated neighbor. Several authors suggest that the Nassariidae even attack their own kind.

The Nassariidae are voracious scavengers. They have often been reported climbing into lobster pots for the dead bait. I have seen hordes of *N. tegula* feeding on putrid animal matter in the shallow pools at Estero de Punta Banda.

MacGinitie (1935) describes the eating method of *N. fossatus.* When a snail discovers a piece of food, it turns over and lies shell downward with its foot held high and tightly wrapped about the food, which is thus hidden while the animal devours it. He also (1949) describes the powerful sucking action of its mouth, located at the end of the long proboscis which can be extended 1.5 inches. These snails cling so tightly to a bit of food that they allow themselves to be lifted entirely out of the water before relaxing their hold.

That the keen olfactory sense of these gastropods is their principal means of finding food is thoroughly established by interesting experiments recorded by Cooke (1895) and MacGinitie (1935).

Predators

The Nassariidae are, in turn, eaten by larger animals. Keep (1935) tells of removing *Nassarius* from the stomach of a fish. According to Tryon (1883), in Italy *Nassarius mutabilis* is prepared for human consumption. Several authors report *Nassarius* shells inhabited by hermit crabs. At Estero de Punta Banda, I have seen many *N. tegula* possessed by hermit crabs. At Bay Farm Island, numbers of *N. obsoletus* had been invaded by these crabs. Of the Nassariidae in the California Academy of Sciences collection, there are shells of *N. catallus*, *N. cerritensis*, and *N. insculptus* retaining crab remnants. This evidence seems to indicate these species are preyed upon, or at least have their shells appropriated, by hermit crabs.

Some Nassariidae seem adapted to escape particular enemies. A striking behavior was observed by Bauer (Flattely, 1922). He watched *Nassarius reticulatus* flee a pursuing starfish, *Astropecten bispinosus*. The snail fled by curious leaps, using its foot as a lever, in the manner of a cockle. The movement was such a convulsive one that Bauer found it difficult to follow, but it appeared to be a kind of somersault. This escaping reflex occurred only when the gastropod was directly touched by the starfish. Also, the snail's body was not everywhere equally sensitive to this stimulus; only when the two tails of the mollusc's foot were touched was the reaction produced. Bauer was unable to induce the reflex either mechanically or chemically—only through the medium of a starfish.

Oviposition

The Nassariidae are dioecious. They lay eggs in strong, leathery capsules, the capsules of each species having a characteristic appearance. Each capsule contains a varying number of ova, and there is competition among the embryos within the capsule, so that only a very small percentage survive.

According to Tryon (1883), *Nassarius reticulatus* deposits its spawn on various objects, such as *Zostera* leaves, which are out of the water only during spring tides. These egg-capsules are tiny, compressed pouches, supported by a tiny stalk and arranged in closely overlapping rows. The larvae remain within the capsule for several days after hatching before escaping through a small aperture at the top of the capsule.

Tryon (1882) says *N. obsoletus* lays its ova-capsules during April and May. These capsules are attached singly and are crowded together. During May, I have seen thousands of capsules of *obsoletus* at Bay Farm Island. The capsules were attached to pilings, to living and dead gastropods and pelecypods, to rocks, driftwood, and the inside of an old rubber tire.

Ricketts and Calvin (1948) state that ovipositing *N. fossatus* may be found among eelgrass during late summer. Burch (1945) says *fossatus* is not seasonal; he records their spawning in Anaheim Bay during January.

The egg-laying process of *N. fossatus* has been observed and recorded in detail by MacGinitie (1931).

Adaptation to Environment

The recurved anterior canal of most *Nassarius* shells aids those gastropods living on a muddy substrate. This structure protects the animal's respiratory organ, the siphon, which projects above the mud, thus allowing the snail to breathe while concealed in the sediment.

In many cases, the color of *Nassarius* shells, by blending with the environment, protects the inhabitants from discovery. For example, the shell of *N. obsoletus* is dark brown or blackish, so it is not easily seen on the mud. The body of this mollusc, too, is a dark color, like the muddy sand in which the animal lives. *N. obsoletus* is made even more inconspicuous by its somewhat latticed shell surface. Particles of substrate collect in the irregularities of this surface and conceal the shell.

TAXONOMIC STUDY

Family *NASSARIIDAE*

These gastropods usually possess a more or less ovate shell with a raised spire and a short, recurved anterior canal. Typically, a callus covers the inner lip, often spreading over the body whorl.

Characteristically, these molluscs develop a long siphon and a broad foot. In almost all species, the foot is divided posteriorly into two slender appendages; the only west coast species lacking such bifurcation is *Nassarius obsoletus*. Eyes are present on the outer bases of the tentacles. The operculum is usually corneous, ovoid in shape, with plain or serrated margins. The lingual teeth are arched and pectinate; the uncini possess a basal horn and, occasionally, intermediate serrations.

Genus NASSARIUS Duméril, 1805

Arcularia Martini, Neves Syst. Conch. Cab., 2: 18, 1771.

Nassarius Duméril, Zool. Analyt., p. 166, 1806 [genus without species]; Froriep's translation, p. 167, 1806, only species added, *Buccinum arcularia* [*fide* Iredale, Malac. Soc. London, Proc. 12: 80, 81, 82, 1916].

Arcularia Link, Beschr. Nat. Samml. Univ. Rostock, p. 126, 1807.

? *Eione* Risso, Hist. Nat. Eur. Mérid., 4: 171, 1826; Herrmannsen, Indicis Gen. Malac., 1: 414, 1847.

"*Nassa* Martini" H. and A. Adams, Gen. Rec. Moll., 1: 116, 1853.

TYPE SPECIES: *Buccinum arcularia* Linnaeus, Syst. Nat., ed. 10, p. 737, 1758; figured by Reeve, Conch. Icon., Vol. 8, *Nassa*, pl. 4, figs. 25a, 25b, 1853.

TYPE LOCALITY: Philippine Islands; Recent (Reeve, 1853).

Since the Nassariidae are molluscs which have been known and collected for many years, they have a long and varied taxonomic history. Martini's genus *Arcularia*, 1771, seems to be the earliest name in the literature. This author named *Arcularia* as a section of *Galeodes* or *Semicassis*, which he called a subgenus of *Cassis*. He included *Arcularia major* Martini in his species list. This species is said to be synonymous with *Buccinum arcularia* Linnaeus. Consequently, *Buccinum arcularia*, by absolute tautonomy, becomes the genotype. However, Martini's work is generally disregarded as not being consistently binomial.

Arcularia Link, 1807, has been used by some authors for this genus. However, it is an absolute synonym of *Nassarius* Duméril.

Dall (1917, 1921) and Oldroyd (1927) used the family name Alectrionidae and the generic name *Alectrion* Montfort, 1810. The type of Montfort's genus was *Buccinum papillosum* Linnaeus, a mollusc which differs greatly from *B. arcularia*, the type of *Nassarius*. The shell of *B. papillosum* is heavy and large, with a thick outer lip, a prominent posterior canal, and a somewhat narrow but heavy callus. As *B. papillosum* differs so much from the west coast species, the use of *Alectrion* for these species has been rejected.

Although Woodring (1946) doubts the validity of using *Nassarius* and prefers "*Nassa*," the opinion of recent authors seems to be to accept *Nassarius* Duméril as a substitute for *Nassa* Lamarck. Froriep (1806), in his translation of Duméril, assigned only the species *Buccinum arcularia* Linnaeus to *Nassarius*. Consequently, this species becomes the genotype by monotypy.

The author's opinion is that *Nassarius* Duméril is the preferable name to use until a comprehensive taxonomic revision of the family is completed.

The question of the valid subgeneric divisions of *Nassarius* also awaits further study. Various subgenera have been proposed, but many are arbitrary and difficult to apply. A general practice has been to use *Schizopyga* for *N. fossatus*, *N. perpinguis*, *N. californianus*, *N. cerritensis*, and *N. mendicus*. *N. tegula* is close to the type of the genus and is considered to represent *Nassarius* proper. The entire family needs careful evaluation before valid subgenera can be recognized. Since only a limited geographic area is covered in the present paper, the author has entirely excluded subgeneric classification.

Twelve species and two subspecies of *Nassarius* live in the area between Cape San Lucas and Cape Flattery. Some of these species are among the earliest molluscs known to science from this area. Only species found living in this area at present are considered here, although many members of the family are also common as fossils.

Nassarius is the only genus of this family found within the area considered here.

KEY TO THE WEST COAST SPECIES OF NASSARIIDAE

A. Orange callus spreading over body whorl .... *Nassarius fossatus*

Orange callus absent .... B

B. Length of shell greater than width of body whorl C

Length of shell approximately equal to width of body whorl ..... *N. corpulentus*

C. With distinct groove over dorsum of anterior canal .... D

Without distinct groove over dorsum of anterior canal .... *N. obsoletus*

D. Narrow shelf just at sutures .... E

Shelf at sutures absent .... F

E. Raised ribs formed by axial lines present within aperture; shell sturdy; maximum length, 26 mm............ *N. perpinguis*

Raised ribs within aperture usually absent; shell thin; maximum length, 37 mm... .... *N. californianus*

F. Callus spreading at least slightly over body whorl .... G

Callus definitely delimited, not spreading over body whorl I

G. Transverse sculpture of definite nodes . H

Transverse sculpture of ribs which do not form definite nodes .... *N. cerritensis*

H. Shell white or with brown spiral bands on body whorl; length approximately 13 mm.................. *N. tegula tiarula*

Shell dark brown or purplish without color bands; length approximately 18 mm. .... *N. tegula*

I. Outer lip sharp and thin; shell slender and elongate .... J

Outer lip swollen; shell not slender and elongate .... K

J. Nodes prominent on body whorl...... .... *N. mendicus cooperi*

Nodes absent or poorly developed on body whorl .... *N. mendicus*

K. Anterior canal somewhat long and curved; length 18 to 27 mm.; whorls angular.... .... *N. pagodus*

Anterior canal short L

L. Transverse sculpture prominent on all whorls .... M

Transverse sculpture prominent only on upper whorls; dominant sculpture of numerous extremely faint spiral lines encircling all whorls .... *N. insculptus*

M. Transverse sculpture forming nodes on body whorl; axial sculpture of impressed lines .... *N. versicolor*

Transverse sculpture not forming nodes on any whorls; axial sculpture of raised lines .... *N. catallus*

Nassarius fossatus (Gould)

Pl. I, Fig. 2

Buccinum elegans Reeve, Zool. Soc. London, Proc. (10): 199, 1843, [non] *Buccinum elegans* Costa, 1822.

Buccinum fossatum Gould, Boston Soc. Nat. Hist., Proc. 3: 152, 1849.

Nassa reevei A. Adams, Zool. Soc. London, Proc. for 1851: 109 [nomen novum for *Buccinum elegans* Reeve].

Nassa fossata Gould, Gabb, Geol. Survey Calif., Paleontol. 2: 74, 1868–69; Cooper, Amer. Jour. Conch. 6: 68, 1870; Keep, West Coast Shells, p. 36, fig. 16, 1893; Packard, Calif. Univ., Pubs., Zool. 18(13): 303, 1918.

Nassa (*Tritia*) *fossata* Gould, Tryon, Man. Conch. I, 4: 55, pl. 17, figs. 316, 317, 1882.

Alectrion fossata Gould, Chace, E. P., Nautilus 29(11): 130, 1916; Jordan, South. Calif. Acad. Sci., Bul. 23: 149, 1924; Johnson and Snook, Seashore Animals of the Pacific Coast, p. 513, fig. 530, 1927.

Alectrion fossatus Gould, Dall, U. S. Natl. Mus., Proc. 51: 575, 1917; Oldroyd, I. S., Wash. Univ., Puget Sound Biol. Sta. Pubs. 4: 95, pl. 22, figs. 3, 4, 1924.

Alectrion (*Schizopyga*) *fossata* Gould, Dall, U. S. Natl. Mus., Bul. 112: 102, 1921; Waterfall, Calif. Univ., Pubs., Geol. Sci. 18: 78, 1929.

Alectrion (*Schizopyga*) *fossatus* Gould, Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser.

Geol. Sci. 2(1): 264, pl. 26, figs. 1, 3, 5, 7, 9, 1927.

Nassarius (*Schizopyga*) *fossatus* (Gould), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 675, pl. 26, figs. 55, 56, 1931; Keep, West Coast Shells, p. 229, fig. 220, 1935.

Nassarius fossatus (Gould), Jordan, Stanford Univ., Dept. Geol. Contrib. 1(4): 107–173, 1936; Smith and Gordon, Calif. Acad. Sci., Proc. IV, 26(8): 187, 1948.

"*Nassa*" *fossata*, Woodring, U. S. Geol. Survey, Prof. Paper 207: 73, 1946.

TYPE LOCALITY: Puget Sound at mouth of Columbia River (Oldroyd, 1927).

DESCRIPTION: Maximum length, 48 mm.; average length, 36 mm.; usually 8 whorls, last whorl pronouncedly ventricose; spiral and transverse ridges over shell surface; conspicuous orange callus on inner lip, spreading over body whorl; outer lip sharp, denticulated by ends of spiral ridges; sutures distinct, deeply impressed; mature specimens often with prominent posterior canal; anterior canal broad, short, sharply reflected; deep fossa at base of body whorl; main shell color ashen.

This species was named *Buccinum elegans* by Reeve, but since *Buccinum elegans* was preoccupied for a fossil species, A. Adams changed the name to *Nassa reevei*, which falls before Gould's prior name of *Buccinum fossatum*.

RECENT GEOGRAPHIC RANGE: Sitka, Alaska, to Cedros Island, Lower California.

HABITAT: Common on mud flats; rare in 10 or 15 fathoms.

Nassarius perpinguis (Hinds)

Pl. II, Figs. 4, 5

Nassa perpinguis Hinds, Zool. Voy. Sulphur, Mollusca, p. 36, pl. 9, figs. 12, 13, 1844; Carpenter, Brit. Assoc. Adv. Sci., Rpt. for 1863: 662, 1864; Tryon, Man. Conch. I, 4: 56, pl. 17, fig. 319, 1882; Keep, West Coast Shells, p. 38, fig. 19, 1893.

Nassa intastriata Conrad, U. S. House of Representatives, House Document 129: 17, July 1855, reprinted by Dall, U. S. Geol. Survey, Prof. Paper 59: 169, 1909.

Nassa interstriata Conrad, U. S. Pacific Railroad Survey 5: 327, 1856, correction in spelling of "intastriata."

Nassa perpinguis Gould, Keep, West Amer. Shells, p. 184, fig. 186, 1904.

Nassa perpinguis var. *bifasciata* Berry, Nautilus 22: 39, 1908.

Alectrion perpinguis Gould, Chace, E. P., Nautilus 29: 130, 1916.

Alectrion perpinguis Hinds, Dall, U. S. Natl. Mus., Proc. 51: 576, 1917; Oldroyd, I. S., Wash. Univ., Puget Sound Biol. Sta. Pubs. 4: 96, pl. 22, fig. 5, 1924; Jordan, South. Calif. Acad. Sci., Bul. 23: 149, 1924; Johnson and Snook, Seashore Animals of the Pacific Coast, p. 513, fig. 532, 1927.

Alectrion (*Schizopyga*) *perpinguis* Hinds, Dall, U. S. Natl. Mus., Bul. 112: 103, 1921; Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci. 2(1): 266, pl. 26, fig. 11, 1927.

Nassarius perpinguis (Hinds), Jordan, Stanford Univ., Dept. Geol. Contrib. 1(4): 114, 1936; Smith and Gordon, Calif. Acad. Sci., Proc. IV, 26(8): 187, 1948.

Nassarius (*Schizopyga*) *perpinguis* (Hinds), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 673, pl. 26, figs. 51, 52, 1931; Keep, West Coast Shells, p. 228, fig. 218, 1935.

"*Nassa*" *perpinguis*, Woodring, U. S. Geol. Survey, Prof. Paper 207: 73, 1946.

TYPE SPECIMEN: Zoological Museum, Copenhagen (Oldroyd, 1927).

TYPE LOCALITIES: Of *perpinguis*, Magdalena Bay, Lower California (Recent); of *intastriata* Conrad, Santa Barbara, California (Pleistocene); of *bifasciata*, San Pedro, California (Recent) (Grant and Gale, 1931).

DESCRIPTION: Maximum length, 26 mm.; average length, about 22 mm.; usually 7 rounded whorls; many sharp, spiral ridges crossed by posteriorly sloping transverse ridges, giving shell reticulate surface; transverse ornamentation typically most prominent on upper whorls, spiral most prominent on lower whorls; transverse ridges sometimes nearly obsolete on body whorl; inner lip with slight callus; outer lip plain, thin; aperture about 1/3 length of shell, ridged inside by spiral sculpture; sutures distinct, usually with narrow shelf just at sutures; short, curved anterior canal; conspicuous groove at base of body whorl; columella spirally ornamented, often with groove on upper part; shell color ashen.

Some specimens of *N. perpinguis* possess one or two bands of darker color around the middle of each whorl (Pl. II, Fig. 4). Berry (1908) named these specimens variety *bifasciata*. However, these shells are now considered merely color variations of no taxonomic significance.

RECENT GEOGRAPHIC RANGE: Puget Sound, Washington, to Magdalena Bay, Lower California.

HABITAT: Common in 10 to 50 fathoms, in sand.

Nassarius californianus (Conrad)

Pl. II, Fig. 6

Schizopyga californiana Conrad, Acad. Nat. Sci. Phila., Proc. for 1856: 315, 1856; Carpenter, Brit. Assoc. Adv. Sci., Rpt. for 1863: 593, 1864.

Schizopyga californica Conrad, Tryon, Man. Conch. I, 4: 55, pl. 3, fig. 32, 1882.

Nassa californiana Conrad, Keep, West Amer. Shells, p. 185, 1904; Arnold, Calif. Acad. Sci., Mem. 3: 231, [non] pl. 4, fig. 3, 1903.

Alectrion (*Schizopyga*) *californiana* Conrad, Dall, U. S. Natl. Mus., Proc. 51: 576, 1917; Dall, U. S. Natl. Mus., Bul. 112: 102, pl. 11, fig. 4, 1921.

Alectrion (*Schizopyga*) *californianus* Conrad, Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci. 2(1): 264, pl. 26, fig. 13, 1927.

Alectrion californiana Conrad, Jordan, South. Calif. Acad. Sci., Bul. 23: 149, 1924.

Nassarius (*Schizopyga*) *californianus* (Conrad), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 672, pl. 26, fig. 49, 1931; Keep, West Coast Shells, p. 228, 1935.

Nassarius californianus (Conrad), Jordan, Stanford Univ., Dept. Geol. Contrib. 1(4): 114, 1936; Smith and Gordon, Calif. Acad. Sci., Proc. IV, 26(8): 187, 1948.

TYPE LOCALITY: Santa Clara, California (Oldroyd, 1927).

There is much confusion concerning *N. californianus*. Woodring (1946) says the species is based on fossil material which has been lost, so the status of this species is uncertain until a neotype is designated. The locality of this type material was near Santa Clara, California, presumably Pliocene. Woodring believes this fossil material probably was the species later described as "*Nassa*" *moraniana*. "*N.*" *moraniana* is an extinct Pliocene species not known to occur in the Pleistocene. He claims the Recent species identified by Dall as *californiana* is not *moraniana* and evidently is not *californiana* and thus needs a new name. Grant and Gale (1931) state, "Whether the shell figured by Dall (1921) as *californianus* is identical with Conrad's presumed Miocene species cannot be said at the present time." Grant and Gale (1931) further state that "Arnold's figure in his San Pedro memoir (1903) is not typical of Conrad's species, and may be of an undescribed variety or even a new species." Woodring (1946) proposes a new name, "*Nassa*" *delosi*, for Arnold's figured *californiana*.

The shell figured by Dall (1921) represents the species generally recognized today as *Nassarius californianus*. Consequently, Dall's species is the basis of the following description.

DESCRIPTION: Maximum length, 37 mm.; average length, 23–25 mm.; 6 or 7 rounded whorls; spiral ribs crossed by transverse ridges; spiral and transverse sculpture about equally well developed, giving shell reticulate surface; sutures well defined; aperture about 1/3 length of shell, with ribs usually not apparent within; outer lip plain; callus usually quite thin; basal groove deep; posterior canal absent; closely resembles *N. perpinguis*, but almost twice as large.

RECENT GEOGRAPHIC RANGE: Oregon coast to San Ignacio Lagoon, Lower California.

HABITAT: 30 to 40 fathoms, in mud and sand; rare.

Nassarius tegula (Reeve)

Pl. II, Fig. 8

Nassa tegula Reeve, Conch. Icon. 8: 98, pl. 15, fig. 98, 1853; Carpenter, Brit. Assoc. Adv. Sci., Rpt. for 1863: 662, 1864; Tryon, Man. Conch. I, 4: 39, pl. 13, figs. 166, 167, 1882; Keep, West Coast Shells, p. 37, fig. 17, 1893; Stearns, U. S. Natl. Mus., Proc. 17: 180, 1894; Arnold, Calif. Acad. Sci., Mem. 3: 235, 1903.

Arcularia tegula Reeve, Dall, U. S. Natl. Mus., Proc. 51: 577, 1917.

Alectrion (*Zeuxis*) *tegula* Reeve, Dall, U. S. Natl. Mus., Bul. 112: 103, 1921; Waterfall, Cal. Univ., Pubs., Geol. Sci. 18: 78, 1929.

Alectrion tegula (Reeve), Jordan, South. Calif. Acad. Sci., Bul. 23: 149, 1924; Johnson and Snook, Seashore Animals of the Pacific Coast, p. 513, fig. 533, 1927.

Alectrion (*Schizopyga*) *tegulus* Reeve, Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci. 2(1): 267, pl. 26, fig. 10, 1927.

Nassarius tegulus, Keen, West North Amer. Mar. Moll., p. 41, 1937.

Nassarius (*Nassarius*) *tegula* (Reeve), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 671, pl. 26, fig. 43, 1931; Keep, West Coast Shells, p. 228, fig. 217, 1935; Jordan, Stanford Univ., Dept. Geol. Contrib. 1(4): 114, 1936.

"*Nassa*" *tegula* Woodring, U. S. Geol. Survey, Prof. Paper 207: 73, 1946.

TYPE SPECIMEN: Cuming Museum, London, England (Oldroyd, 1927).

TYPE LOCALITY: Habitat unknown (Reeve, 1853); California or Lower California (Oldroyd, 1927).

DESCRIPTION: Maximum length, 21 mm.; average length, 16–18 mm.; typically 6 whorls; spire short and sharp; low axial folds becoming nodose at shoulders of whorls; sometimes faint spiral ridges; typically, body whorl smooth below nodes; prominent callus on parietal wall of body whorl; outer lip often thickened externally, denticulate; sutures distinct; aperture usually slightly greater than 1/3 length of shell with small canal at each end; groove at base of body whorl; much color variation, frequently purplish brown.

RECENT GEOGRAPHIC RANGE: San Francisco, California, to Lower California.

HABITAT: Common on mud flats.

Nassarius tegula tiarula (Kiener) new comb.

Pl. I, Fig. 4

Buccinum tiarula Kiener, Spéc. Gén. et Icon. des Coq. Viv. (2): 111, pl. 30, fig. 4, 1834.

Nassa tiarula Kiener, Tryon, Man. Conch. I, 4: 41, pl. 12, figs. 174–178, 1882.

Arcularia tiarula Kiener, Dall, U. S. Natl. Mus., Proc. 51: 577, 1917.

Nassarius tiarulus (Kiener), Jordan, Stanford Univ., Dept. Geol. Contrib. 1(4): 114, 1936.

DESCRIPTION: Maximum length, 18 mm.; average length, 13–15 mm.; shell small, strong; spire short, sharp; typically 7 or 8 whorls; body whorl about ½ length of shell; ornamentation of low axial folds, nodose at shoulders of whorls; body whorl usually smooth below nodes; sometimes faint spiral ribs; noticeable callus on inner lip; outer lip usually thickened; aperture slightly greater than 1/3 length of shell, denticulate within; sutures impressed, wavy; groove at base of body whorl not prominent; anterior canal short, recurved; posterior canal small; much color variation; basic color usually whitish or faintly yellow, often with varying numbers of brown spiral bands, particularly on body whorl; often highly polished.

This species is exceedingly variable, particularly in color and ornamentation. Some specimens possess no spiral threads, while others have such threads running around the entire shell, even on the body whorl, which is typically smooth. The transverse ridges and nodes are seldom the same in number or in size.

This mollusc was described by Kiener (1834) as a separate species, while Stearns (1894), Grant and Gale (1931), and others have put it into synonymy with *Nassarius tegula*. In my opinion, however, *N. tiarula* is a subspecies of *N. tegula*. *N. tiarula* has a more southern range than does *N. tegula*, *tiarula* ranging from Panama to Lower California, while *tegula* ranges from Lower California as far north as San Francisco. Also, *tiarula* has a smaller shell and finer sculpture than does *tegula*. The color of the two forms is usually different; *tiarula* is generally white or yellowish, while *tegula* is usually purplish brown. Of course, variations from the typical form of each are often seen, particularly where their geographic ranges overlap.

RECENT GEOGRAPHIC RANGE: Lower California to Panama.

HABITAT: Mud flats or in a few fathoms.

Nassarius cerritensis (Arnold)

Pl. II, Fig. 7

Nassa cerritensis Arnold, Calif. Acad. Sci., Mem. 3: 231, pl. 4, fig. 1, 1903.

Alectrion cerritensis Arnold, Dall, U. S. Natl. Mus., Proc. 51: 576, 1917; Jordan, South. Calif. Acad. Sci., Bul. 23: 149, 1924.

Alectrion (*Schizopyga*) *cerritensis* Arnold, Dall, U. S. Natl. Mus., Bul. 112: 102, 1921; Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci., 2(1): 266, 1927.

Nassarius (*Schizopyga*) *cerritensis* (Arnold), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 675, 1931.

Nassarius cerritensis (Arnold), Jordan, Stanford Univ., Dept. Geol. Contrib. 1(4): 114, 1936.

"*Nassa*" *cerritensis* Arnold, Woodring, U. S. Geol. Survey, Prof. Paper 207, pl. 35, figs. 16–19, 1946.

TYPE SPECIMEN: U. S. National Museum, No. 162,553 (Grant and Gale, 1931).

TYPE LOCALITY: Los Cerritos (Signal Hill), Los Angeles County (Pleistocene).

DESCRIPTION: Maximum length, 20 mm.; average length, about 17 mm.; 7 to 8 somewhat rounded whorls; several prominent, rounded, transverse ridges, not forming nodes, crossed by several sharp, raised, spiral lines, giving reticulate surface; cancellation not as prominent as in *N. californianus* or *N. perpinguis;* inner lip smooth with thin callus spreading somewhat onto body whorl; outer lip thickened internally by denticulated ridge; sutures wavy; deep groove below body whorl; short, broad, recurved anterior canal.

RECENT GEOGRAPHIC RANGE: Lower California to Gulf of California.

Dall (1917) claims this species is found living from San Pedro to the Gulf of California. However, Burch (1945) says, "It is a common fossil in local Pleistocene deposits but seems to be of the southern [Recent] fauna. The consensus of opinion regarding this species is stated by Dr. George Willett briefly, 'Probably lower Californian.' " Woodring (1946) states that, according to numerous specimens in the National Museum, a small race of *cerritensis* or a closely related species is living along the Lower California coast at Point Abreojos and Ballenas Bay and in the Gulf of California at Guaymas.

I agree that *N. cerritensis* does not belong to the Recent fauna of the west coast of California, although it apparently lives on the Lower California coast. I have never found any specimens living on our coast, nor have I located any specific record of its being taken alive on this coast. Statements in the literature of occurrences at Long Beach (Grant and Gale, 1931) and Santa Monica (Keen, 1937) probably refer to fossil collections.

HABITAT: 20 to 30 fathoms.

Nassarius mendicus (Gould)

Pl. I, Fig. 3

Nassa mendica Gould, Boston Soc. Nat. Hist., Proc. 3: 155, 1851; Carpenter, Brit. Assoc. Adv. Sci., Rpt. for 1863: 662, 1864; Tryon, Man. Conch. IV, 4: 56, pl. 17, figs. 320–323, 1882; Keep, West Coast Shells, p. 37, [non] fig. 18, 1893; Arnold, Calif. Acad. Sci., Mem. 3: 233, 1903.

Nassa woodwardi Forbes, Zool. Soc. London, Proc. for 1850: 273, pl. 11, fig. 3, 1850.

Nassa gibbsii W. Cooper, U. S. Pacific Railroad Rpts., Sup. to 1(3): 371, 1859.

Alectrion mendicus Gould, Dall, U. S. Natl. Mus., Proc. 51: 576, 1917; Oldroyd, I. S., Wash. Univ., Puget Sound Biol. Sta., Pubs. 4: 95, pl. 22, fig. 6, 1924; Jordan, South. Calif. Acad. Sci., Bul. 23: 149, 1924.

Alectrion (*Schizopyga*) *mendica* Gould, Dall, U. S. Natl. Mus., Bul. 112: 102, 1921; Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci. 2(1): 265, pl. 26, fig. 2, [non] figs. 6, 14, 1927.

Alectrion cooperi var. *woodwardi* Forbes, Oldroyd, I. S., U. S. Natl. Mus., Proc. 65(22): 12, 1925.

Alectrion mendica (Gould), Johnson and Snook, Seashore Animals of the Pacific Coast, p. 513, [non] fig. 531, 1927.

Nassarius (*Schizopyga*) *mendicus* (Gould), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 674, pl. 26, fig. 54 [immature], 1931; Keep, West Coast Shells, p. 229, [non] fig. 219, 1935.

Nassarius mendicus (Gould), Jordan, Stanford Univ., Dept. Geol. Contrib. 1(4): 114, 1936; Smith and Gordon, Calif. Acad. Sci., Proc. IV, 26(8): 187, 1948.

"*Nassa*" *mendica*, Woodring, U. S. Geol. Survey, Prof. Paper 207: 73, 1946.

TYPE SPECIMEN: Boston Society of Natural History (Oldroyd, 1927).

TYPE LOCALITY: Nisqually, Port Discovery, Puget Sound (Oldroyd, 1927). According to Burch (1945), A. M. Keen states that, "The holotype label of *N. mendicus* at the National Museum gives the type locality as Straits of Fuca."

DESCRIPTION: Maximum length, 25 mm.; average length, about 14 mm.; shell elongate; spire elevated; 6 to 7 whorls; length of body whorl almost half the shell length; many fine, raised, spiral threads crossed by fewer, coarser, transverse ridges; definitely delimited white callus on inner lip, not spreading over body whorl; outer lip sharp, simple; line of about 10 raised ribs within aperture, not reaching edge of lip; definite groove at base of body whorl; anterior canal broad, short, slightly reflected; posterior canal typically absent; shell color usually reddish brown or light ashen.

RECENT GEOGRAPHIC RANGE: Forrester Island, Alaska, to Magdalena Bay, Lower California.

HABITAT: 5 to 40 fathoms, in sand.

Nassarius mendicus cooperi (Forbes)

Pl. I, Fig. 1

Nassa cooperi Forbes, Zool. Soc. London, Proc. for 1850: 273, pl. 11, fig. 4, 1850; Carpenter, Brit. Assoc. Adv. Sci., Rpt. for 1863: 662, 1864; Keep, West Coast Shells, p. 37, figs. 18, 1893.

Nassa mendica Gould var. *cooperi* Forbes, Dall, U. S. Natl. Mus., Proc. 19: 377, pl. 33, fig. 9, 1897; Arnold, Calif. Acad. Sci., Mem. 3: 234, 1903; Berry, Nautilus 22: 38, 1908.

Alectrion mendica cooperi Forbes, Chace, E. P., Nautilus 29(11): 130, 1916.

Alectrion cooperi Forbes, Dall, U. S. Natl. Mus., Proc. 51: 576, 1917; Oldroyd, I. S., Wash. Univ., Pubs., Puget Sound Biol. Sta. 4: 96, 1924.

Alectrion (*Schizopyga*) *cooperi* Forbes, Dall, U. S. Natl. Mus., Bul. 112: 102, 1921; Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci. 2(1): 265, pl. 26, fig. 8, 1927.

Nassarius (*Schizopyga*) *mendicus cooperi* (Forbes), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 674, pl. 26, figs. 40, 50, 1931; Keep, West Coast Shells, p. 229, fig. 219, 1935.

Nassarius (*Schizopyga*) *cooperi* (Forbes), Vokes, Nautilus 50(2): 47, 1936.

"*Nassa*" *mendica cooperi*, Woodring, U. S.

Geol. Survey, Prof. Paper 207: 73, pl. 34, fig. 12, 1946.

Nassarius cooperi (Forbes), Smith and Gordon, Calif. Acad. Sci., Proc. IV, 26(8): 187, 1948.

TYPE SPECIMEN: British Museum? (Oldroyd, 1927).

TYPE LOCALITY: Said to be "Sandwich Islands," probably a ballast shell (Oldroyd, 1927).

DESCRIPTION: The preceding description of *Nassarius mendicus* may be applied to *cooperi* except that the transverse sculpture is more pronounced on the latter form; the longitudinal ridges become actual nodes in the middle of the whorls on *cooperi*.

Several authors place *N. cooperi* in synonymy with *N. mendicus*. However, I am inclined to call *cooperi* a subspecies. It is true that these two forms occur together at many points along the Pacific coast. However, most authors give Alaska as the northernmost range of *mendicus* and Puget Sound as the northernmost range of *cooperi*. Thus, *cooperi* seems to be a more southern form. It is also true that several workers record collections of specimens showing perfect intergradation between the two forms. However, I believe that the difference between the typical *mendicus*, having relatively smooth whorls completely lacking nodes, and the prominently tubercled *cooperi* is sufficient to separate *cooperi* as a subspecies of *mendicus*.

RECENT GEOGRAPHIC RANGE: Puget Sound, Washington, to San Diego, California.

HABITAT: 3 to 24 fathoms, in sand.

Nassarius pagodus (Reeve)

Pl. I, Fig. 7

Triton pagodus Reeve, Conch. Icon. 2: 97, pl. 20, fig. 97, 1843.

Buccinum decussatum Kiener, Spéc. Gén. et Icon. des Coq. Viv. (2): 109, pl. 30, fig. 3, 1834.

Nassa pagoda Reeve, Tryon, Man. Conch. I, 4: 45, pl. 14, figs. 226–228, 1882; Pilsbry and Lowe, Acad. Nat. Sci. Phila., Proc. 84: 115, 1932.

Alectrion pagoda Reeve, Dall, U. S. Natl. Mus., Proc. 51: 576, 1917.

Nassarius pagodus Reeve, Strong, Hanna, and Hertlein, Calif. Acad. Sci., Proc. IV, 21(10): 119, 1933.

TYPE SPECIMEN: In Cuming collection, Museum Norris? (Reeve, 1844).

TYPE LOCALITY: Bay of Montija, West Columbia (Reeve, 1844).

DESCRIPTION: Maximum length, 27 mm.; average length, about 23 mm.; usually 8 whorls; prominent transverse ridges forming angular nodes in middle of whorls; fine spiral threads; inner lip with definitely margined callus, not spreading over body whorl; prominent tooth on upper part of columella; outer lip swollen; somewhat long, recurved anterior canal; wide, deep groove at base of body whorl; aperture almost half length of shell, denticulate within; shell color varies, often white or yellowish or variously banded with brown.

RECENT GEOGRAPHIC RANGE: Cape San Lucas, Lower California, to Panama.

HABITAT: 3 to 40 fathoms; also on mud flats.

Nassarius versicolor (C. B. Adams)

Pl. I, Fig. 5

Nassa versicolor C. B. Adams, N. Y. Lyceum Nat. Hist., Ann. 5: 66 [pagination of separate], 1852; Cooper, J. G., Calif. Acad. Sci., Proc. II, 5: 45, 1895.

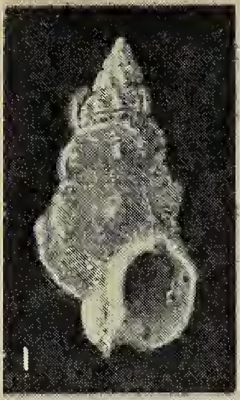
Nassa versicolor var. *striatula* C. B. Adams, N. Y. Lyceum Nat. Hist., Ann. 5: 66, 1852.

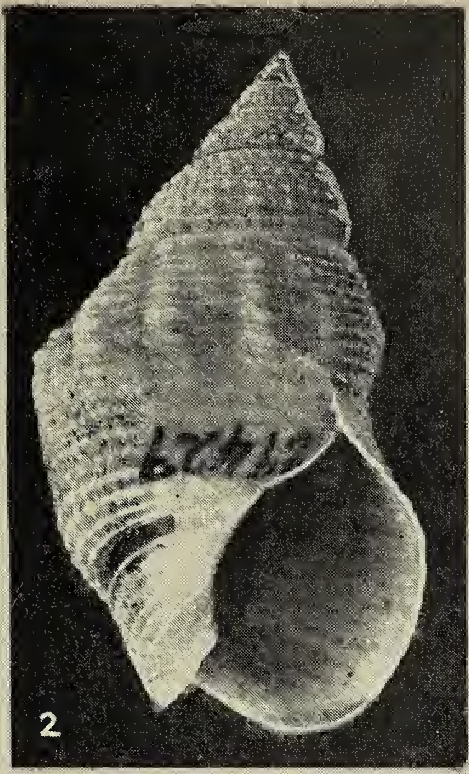
Nassa (*Hima*) *versicolor* C. B. Adams, Tryon, Man. Conch. I, 4: 50, pl. 15, fig. 270, 1882.

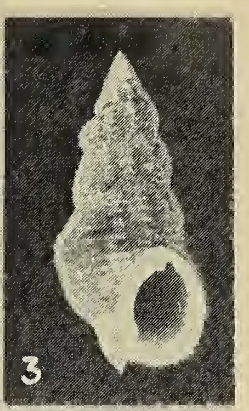
Alectrion versicolor C. B. Adams, Dall, U. S. Natl. Mus., Proc. 51: 576, 1917.

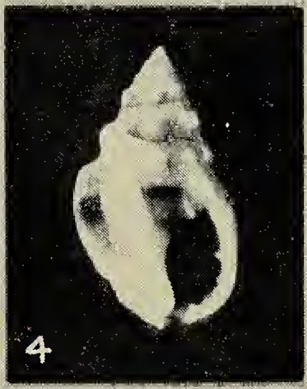
Nassarius versicolor (C. B. Adams), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 677, 1931.

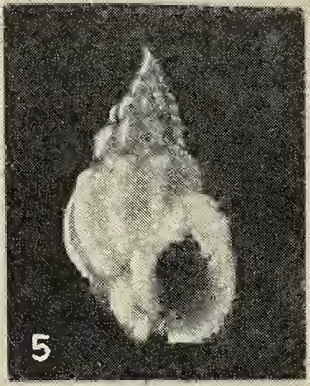
Nassarius versicolor (A. Adams), Jordan, Stan-

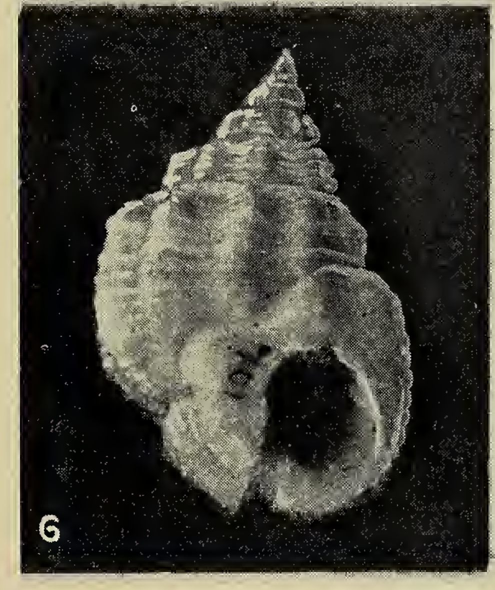


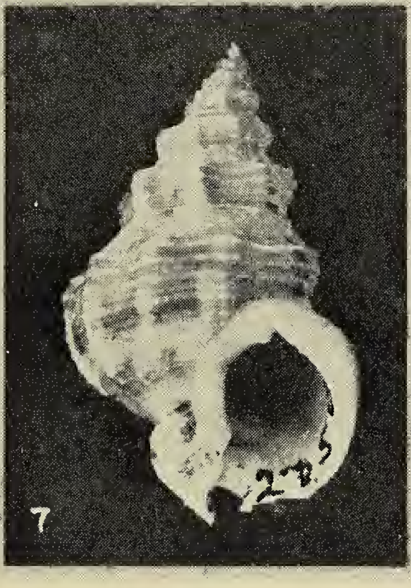












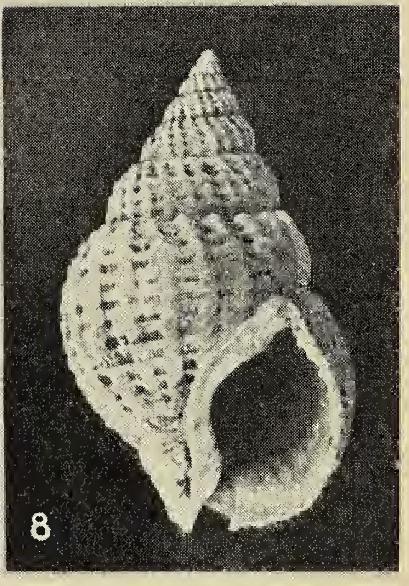


PLATE I

(All measurements are actual dimensions of specimens photographed)

FIG. 1. *Nassarius mendicus cooperi* (Forbes); Santa Rosa Island, California. Calif. Acad. Sci. Loc. 23681. Length: 15 mm. Max. diameter: 7.9 mm.

FIG. 2. *Nassarius fossatus* (Gould); Long Beach, California. Calif. Acad. Sci. Loc. 29429. Length: 37.9 mm. Max. diameter: 22.5 mm.

FIG. 3. *Nassarius mendicus* (Gould); 20 to 30 fathoms in Monterey Bay, California. Calif. Acad. Sci. Loc. 24147. Length: 14.6 mm. Max. diameter: 6.8 mm.

FIG. 4. *Nassarius tegula tiarula* (Kiener); Puerto Escondido, Gulf of California. Calif. Acad. Sci. Loc. 23805. Length: 13.0 mm. Max. diameter: 7.3 mm.

FIG. 5. *Nassarius versicolor* (C. B. Adams); 12 to 15 fathoms in Port Parker, Costa Rica. Calif. Acad. Sci. Loc. 17924. Length: 13.8 mm. Max. diameter: 7.9 mm.

FIG. 6. *Nassarius corpulentus* (C. B. Adams); Margarita Island, Lower California. Calif. Acad. Sci. Loc. 701 (H. Hemphill Coll.). Length: 19.2 mm. Max. diameter: 13.5 mm.

FIG. 7. *Nassarius pagodus* (Reeve); near Mazatlan, Mexico. Calif. Acad. Sci. Loc. 27581. Length: 27.3 mm. Max. diameter: 17.3 mm.

FIG. 8. *Nassarius catallus* (Dall); 35 to 40 fathoms in the Gulf of Chiriqui, Panama. Calif. Acad. Sci. Loc. 17986. Length: 20.8 mm. Max. diameter: 12.5 mm.

ford Univ., Dept. Geol. Contrib. 1(4): 114, 1936.

TYPE LOCALITY: Panama; Recent (Grant and Gale, 1931).

DESCRIPTION: Maximum length, 17 mm.; average length, 13–15 mm.; usually 7 whorls; length of body whorl almost half shell length; sculpture of numerous, evenly spaced spiral grooves, crossed by fewer prominent transverse ridges, forming nodules at tops of first 3 whorls; sculpture faint on upper whorls; inner lip with definitely delimited callus, not spreading over body whorl; outer lip somewhat thickened; aperture denticulate within; sutures distinct, wavy; shallow groove at base of body whorl; anterior canal short, broad, curved; sometimes a small posterior canal with a distinct ridge below it on columella; color usually white with scattered brown spots or bands; much variation in color and amount of sculpture.

RECENT GEOGRAPHIC RANGE: Magdalena Bay, Lower California, to Payta, Peru.

HABITAT: 3 to 45 fathoms.

Nassarius catallus (Dall) new comb.

Pl. I, Fig. 8

Alectrion (*Hima*) *catallus* Dall, Harvard Univ., Mus. Compar. Zool., Bul. 43(6): 307, pl. 11, fig. 11, 1908.

Alectrion catallus Dall, U. S. Natl. Mus., Proc. 51: 576, 1917.

TYPE SPECIMEN: U. S. National Museum (Dall, 1908).

TYPE LOCALITY: U. S. S. "Albatross" Station 3355, Gulf of Panama (Dall, 1908).

DESCRIPTION: Shell solid; spire acute; usually 8 whorls; sharp reticulate sculpture of many axial riblets and larger transverse ridges; sutures very distinct, not channeled; callus definitely margined; aperture rounded-quadrate with about 19 rather distinct axial ribs within; outer lip with strong varix; usually 1 or 2 elongate pustules on columella below posterior canal; anterior canal short, recurved; deep sulcus at base of body whorl.

RECENT GEOGRAPHIC RANGE: Off San Miguel Island, California, to Panama.

HABITAT: 20 to 182 fathoms; rare.

Nassarius insculptus (Carpenter)

Pl. II, Figs. 1, 3

Nassa insculpta Carpenter, Brit. Assoc. Adv. Sci., Rpt. for 1863: 662, 1864; Arnold, Calif. Acad. Sci., Mem. 3: 233, 1903.

Nassa (*Zeuxis*) *insculpta* Carpenter, Tryon, Man. Conch. I, 4: 38, pl. 12, fig. 154, 1882.

Alectrion insculptus Carpenter, Dall, U. S. Natl. Mus., Proc. 51: 576, 1917.

Alectrion insculptus eupleura Dall, U. S. Natl. Mus., Proc. 51: 576, 1917.

Alectrion (*Zeuxis*) *insculptus* Carpenter, Dall, U. S. Natl. Mus., Bul. 112: 103, 1921.

Alectrion (*Zeuxis*) *insculptus eupleura* Dall, U. S. Natl. Mus., Bul. 112: 103, 1921.

Alectrion (*Schizopyga*) *insculptus* Carpenter, Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci. 2(1): 267, pl. 26, fig. 12, 1927.

Alectrion (*Schizopyga*) *insculptus eupleura* Dall, Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci. 2(1): 267, 1927.

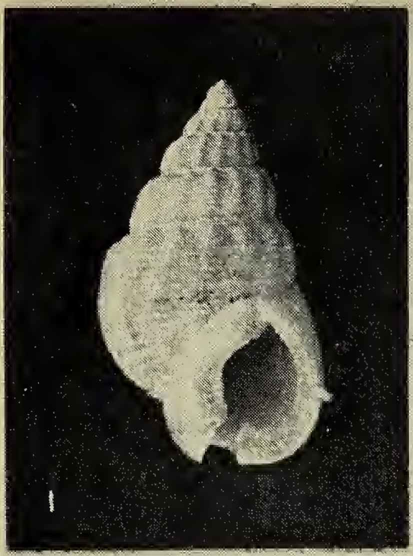
Nassarius insculptus (Carpenter), Grant and Gale, San Diego Soc. Nat. Hist., Mem. 1: 677, 1931; Keen, A. M., West North Amer. Mar. Moll., p. 41, 1937; Smith and Gordon, Calif. Acad. Sci., Proc. IV, 26(8): 187, 1948.

Nassarius eupleurus, Keen, A. M., West North Amer. Mar. Moll., p. 41, 1937.

"*Nassa*" *insculpta*, Woodring, Bramlette, and Kew, U. S. Geol. Survey, Prof. Paper 207: 73, pl. 29, fig. 27, 1946.

TYPE SPECIMENS: Of *insculptus:* State Collection, University of California (Oldroyd, 1927). Of *eupleura:* U. S. National Museum, No. 209046 (Dall, 1917).

TYPE LOCALITIES: Of *insculptus:* 3 to 40 fathoms off Catalina Island, California (Recent). Of *eupleura:* Not stated by Dall, but somewhere between San Simeon, California, and Cedros Island, Lower California (Grant and Gale, 1931).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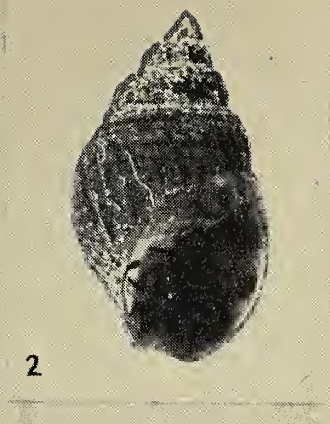
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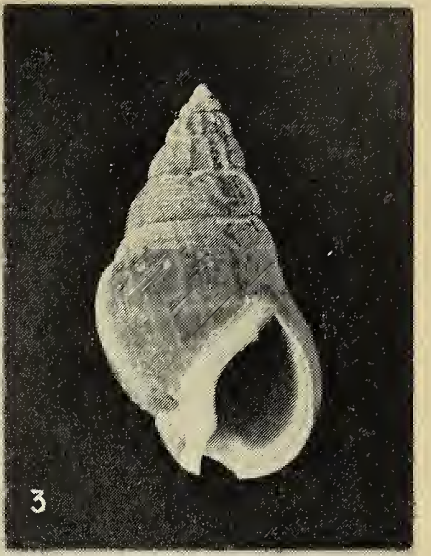
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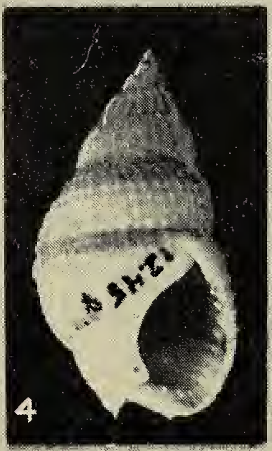
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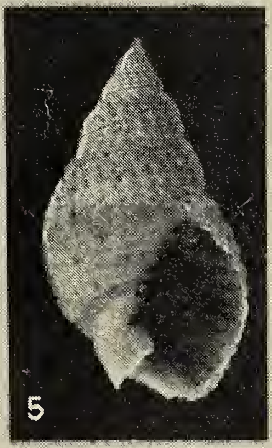
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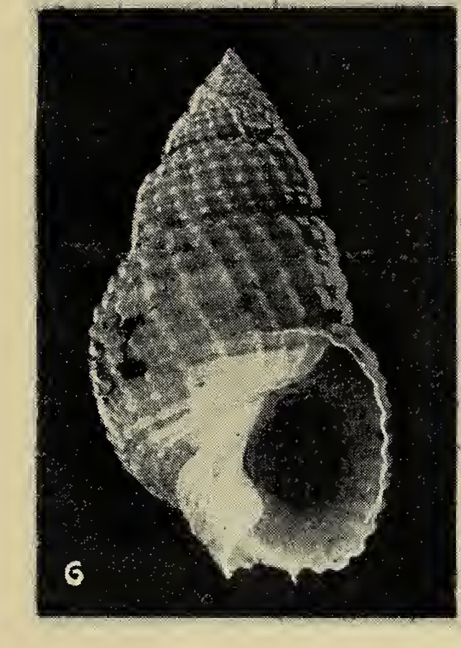
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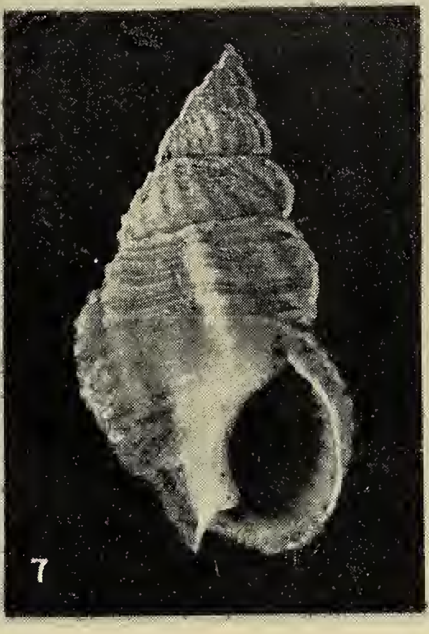
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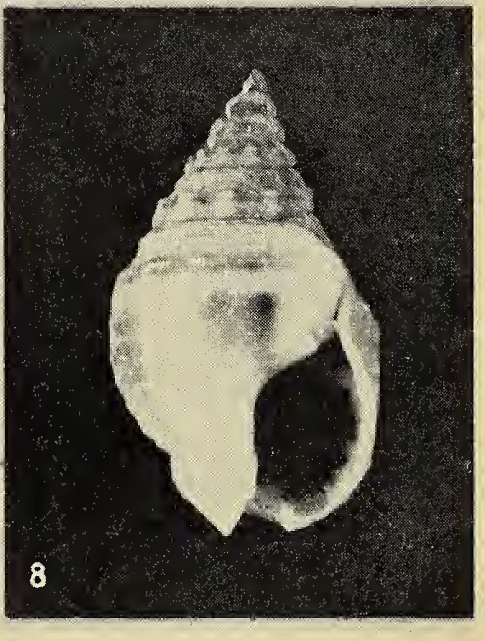
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PLATE II

(All measurements are actual dimensions of specimens photographed)

FIG. 1. *Nassarius insculptus* (Carpenter); Cortez Banks, California. The variation possessing transverse ridges on the body whorl, named *eupleura* by Dall (1917). Calif. Acad. Sci. Loc. 27602. Length: 16.9 mm. Max. diameter: 9.6 mm.

FIG. 2. *Nassarius obsoletus* (Say); Alameda, California. Introduced with oysters from eastern states. Calif. Acad. Sci. Loc. 15159.

FIG. 3. *Nassarius insculptus* (Carpenter); Cortez Banks, California. Calif. Acad. Sci. Loc. 27602. Length: 23.0 mm. Max. diameter: 13.0 mm.

FIG. 4. *Nassarius perpinguis* (Hinds); San Diego, California. The banded variation called *bifusciata* by Berry (1908). Calif. Acad. Sci. Loc. 12458. Length: 16.8 mm. Max. diameter: 9.4 mm.

FIG. 5. *Nassarius perpinguis* (Hinds); San Pedro, California. Calif. Acad. Sci. Loc. 25459. Length: 19.2 mm. Max. diameter: 10.9 mm.

FIG. 6. *Nassarius californianus* (Conrad); 30 fathoms off Point Bonito, California. Calif. Acad. Sci. Loc. 28592. Length: 30.7 mm. Max. diameter: 16.7 mm.

FIG. 7. *Nassarius cerritensis* (Arnold); 20 to 30 fathoms in San Bartolome Bay, Lower California. Calif. Acad. Sci. Loc. 32294. Length: 21.8 mm. Max. diameter: 11.8 mm.

FIG. 8. *Nassarius tegula* (Reeve); San Diego, California. Calif. Acad. Sci. Loc. 24820. Length: 18.8 mm. Max. diameter: 11.7 mm.

DESCRIPTION: Maximum length, 23 mm.; average length, 18–22 mm.; usually 7 whorls; numerous fine, spiral furrows, most prominent on lower portion of body whorl; typically, no transverse sculpturing except on last few whorls; definitely margined callus on inner lip, not spreading over body whorl; spiral sculpture usually apparent through callus; outer lip thickened by slightly denticulate ridge; columella often separated from body whorl by deep, narrow groove; anterior canal short, broad, curved.

Typical *N. insculptus* possesses no transverse sculpture on the body whorl or the penultimate whorl. In my opinion, the form *eupleura*, in which the axial ribs continue onto the body whorl, is a variation of no taxonomic value. I have seen collections containing specimens grading from the typical *insculptus*, with no longitudinal ridges on the body whorl, to specimens possessing conspicuous transverse ribs on the body whorl. The ribbed form cannot be called a subspecies because its geographic range coincides with that of the typical form.

RECENT GEOGRAPHIC RANGE: Point Arena, California, to Cedros Island, Lower California.

HABITAT: 10 to 200 fathoms, in mud, sand, gravel; rare.

Nassarius obsoletus (Say)

Pl. II, Fig. 2

Nassa obsoleta Say, Acad. Nat. Sci. Phila., Jour. 2: 232, 1822.

Nassa (*Ilyanassa*) *obsoleta* Say, Tryon, Man. Conch. I, 4: 60, pl. 18, figs. 237–249, 1882.

Ilyanassa obsoleta Say, Dall, Nautilus 21: 91, 1907; U. S. Natl. Mus., Proc. 51: 578, 1917.

Alectrion (*Ilyanassa*) *obsoleta* Say, Dall, U. S. Natl. Mus., Bul. 112: 103, 1921; Oldroyd, I. S., Stanford Univ., Pubs., Univ. Ser. Geol. Sci. 2(1): 269, pl. 26, fig. 15, 1927.

Nassarius (*Ilyanassa*) *obsoletus* Say, Keep, West Coast Shells, p. 230, 1935.

Nassarius obsoletus, Keen, A. M., West North Amer. Mar. Moll., p. 41, 1937.

TYPE SPECIMEN: Philadelphia Academy of Natural Sciences (Oldroyd, 1927).

TYPE LOCALITY: East coast (Oldroyd, 1927).

DESCRIPTION: Maximum length, 25 mm.; average length, about 20 mm.; shell solid; 6 or 7 convex whorls; sutures simple, not deeply impressed; body whorl longer than length of spire; apex blunt, usually broken; numerous faint spiral ribs crossed at an angle by slightly raised transverse ridges; cancellate sculpture sometimes giving granulated appearance to shell surface, particularly on upper whorls; outer lip plain or slightly thickened at edge; aperture often lineated within by elevated, interrupted spiral lines; thin white or brownish callus on inner lip, spreading only slightly onto body whorl; posterior canal typically absent, if present a faint groove; anterior canal but a slight notch; no groove at base of body whorl; shell dark reddish brown, blackish, or lighter brown, sometimes tinged with olive green or banded with lighter color.

This species is called the "Worn-Out Dog Whelk" because of its eroded appearance. Rarely are perfect shells found, since the spire is usually broken at the apex. This species lacks the bifurcated foot typical of most Nassariidae.

RECENT GEOGRAPHIC RANGE: On West Coast: Boundry Bay, British Columbia; San Francisco, Oakland, Alameda, and Palo Alto, California. Introduced from east coast with oyster seed.

HABITAT: Flourishing on oyster beds and mud flats.

Nassarius corpulentus (C. B. Adams)

Pl. I, Fig. 6

Nassa corpulenta C. B. Adams, N. Y. Lyceum Nat. Hist., Ann. 5: 284, 529 [pagination of separate: 60, 305], 1852; Stearns, U. S. Natl. Mus., Proc. 17: 181, 1894; Pilsbry and Lowe, Acad. Nat. Sci. Phila., Proc. 84: 115, 1932.

Nassarius corpulenta C. B. Adams, Bales, Nautilus 52: 45, 1938.

DESCRIPTION: Maximum length, 20 mm.; average length, about 17 mm.; 7 or 8 convex whorls; body whorl longer than half length of shell; body whorl almost as wide as length of shell; sutures impressed, somewhat wavy; several prominent transverse ridges, most noticeable on first 3 whorls, forming small nodes near sutures; many fine, evenly-spaced, raised, spiral threads; outer lip considerably thickened; row of denticles within aperture; columella concave, covered with heavy callus, which is often denticulate; posterior canal faintly indicated on some specimens; anterior canal short, rather broad, slightly reflected; deep groove at base of body whorl; shell whitish or ashen, often with few brown bands encircling body whorl.

RECENT GEOGRAPHIC RANGE: Cape San Lucas, Lower California, to Colombia.

Species of Doubtful Occurrence or Uncertain Systematic Position

Several Nassariidae reportedly have been collected within the area treated in this paper which, in my opinion, do not belong to this fauna. These species are discussed below.

Nassarius nodicinctus (A. Adams)

Dall (1921) states that *N. nodicinctus* ranges from San Diego, California, to Panama and the Galapagos Islands. This range has been copied by succeeding authors, such as Oldroyd (1927) and Keen (1937). However, these authors cite no actual specimens taken as far north as San Diego. In the collections consulted, there were no specimens from the west coast of North America; all were from the Galapagos Islands. I have located no mention, other than Dall's report, of specimens found in this area. In collecting along the California coast, I have never discovered *N. nodicinctus*. Furthermore, the type locality of this species is in the Galapagos. For these reasons, I believe Dall's record from San Diego is a mistake perpetuated by subsequent conchologists and that this species should be excluded from the faunal record for this area.

Nassarius noduliferus (Philippi)

N. noduliferus is also reported by Dall (1921) to occur at San Diego, ranging from San Diego to the Gulf of California. Here again, Oldroyd (1927) and Keen (1937) record the same range. However, in this case too, I have found no record, either in the collections or the literature, of actual specimens from the west coast. Also, the type locality of *noduliferus* is in the China Seas. In my opinion, this species definitely is not a member of the west coast fauna.

Nassarius nodiferus (Powys)

N. nodiferus, recognized by Carpenter (1864) as living in Panama and the Galapagos, has been confused with *N. noduliferus*. *N. nodiferus* is not a west coast form either; I have found no record of its being taken from this coast, and I have never collected it here myself.

Alectrion tschudii (Troschel)

If Dall's (1917) report of a species named *Alectrion tschudii*, ranging from Cedros Island, Lower California, to Peru, is correct, this mollusc should be included in this paper, since it would occur within the area from Cape San Lucas to Cape Flattery. However, in my opinion, this name should be discarded entirely. In all the literature, Dall's reference to this species is the only one I have located. Dr. Howard Hill, Curator of Zoology at the Los Angeles County Museum, writes (personal communication) that *A. tschudii* is a name given the juvenile form of *Nassarius dentiferus*. Since *N. dentiferus* lives in Mexico, Panama, and Peru, not ranging as far north as Cape San Lucas, it is not considered in this paper.

Alectrion lirata (Dunker)

A. lirata should merely be mentioned in this list. Bonnot (1935) reports that a shipment of Japanese seed oysters was inspected at Elkhorn Slough. The *Nassarius* specimens therein were identified by Dr. Paul Bartsch of the U. S. National Museum as *Alectrion lirata* (Dunker). However, this is the only reference to this species' being found on our coast, so I assume that, unlike *N. obsoletus*, it has not become established in this area.

Nassarius onchodes (Dall)

Dall (1917) described a species of Nassariidae which he named *Alectrion onchodes*, ranging from Cedros Island, Lower California, to Panama. This species was never figured. In the collections, I found no example of this mollusc. Although Jordan (1936) reports *N. onchodes* from the Pleistocene of Magdalena Bay, Lower California, I have discovered no other record of its being collected either living or as a fossil. Consequently, the position of this species remains uncertain.

Nassarius mendicus indisputabilis (Oldroyd)

The systematic status of *N. mendicus indisputabilis* is also problematic. This mollusc was figured and named as a subspecies of *N. mendicus* by Oldroyd (1927), but no description of it was given. According to Grant and Gale (1931), *indisputabilis* is of no value. However, although I was able to locate only two specimens identified as *indisputabilis*, they do differ from typical *mendicus*, as well as from the subspecies *cooperi*. The shells of *indisputabilis* are about 8 millimeters in length, smaller than *mendicus* or *cooperi*. The sculpture of *indisputabilis* is sharper, the axial threads being more prominent than on either *mendicus* or *cooperi*. Unlike either *mendicus* or *cooperi*, the transverse and axial ornamentation is about equally well developed and distinct on all whorls. Both the basal groove and the anterior canal of *indisputabilis* are larger in relation to shell size than on *mendicus* or *cooperi*. *N. indisputabilis* seems to have a more northern range than *mendicus* or *cooperi;* the specimens I examined, housed at the California Academy of Sciences, were from Annette Island, Alaska.

Further to confuse the question, the California Academy of Sciences specimens of *indisputabilis* are much closer to Oldroyd's (1927) Figure 14, representing *mendicus*, than to Oldroyd's (1927) Figure 4, which supposedly shows *indisputabilis*. Until a description of *indisputabilis* is published and more specimens are collected, the true position of this form cannot be determined.

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Iodine Content of Some Marine Algae[1]

MADELON R. GRIMM[2]

THE LITERATURE ON IODINE and iodide content of marine algae has been reviewed by Fritsch (1945), Chapman (1950), and Smith (1951). To their extensive bibliographies, the contributions of Turrentine (1912) and Cameron (1914, 1915) may be added.

Since many of the early investigators were interested primarily in the economic aspects of the algae, they generally disregarded the suitability of the species studied for laboratory use. For example, their interests were concerned with the extraction and utilization of iodine for dietary and medicinal purposes. The use of this substance in fertilizer resources was also promoted.

In recent years the use of iodine in tracer studies with its many applications necessitates an expanded spectrum of available species of algae to determine which organisms lend themselves to further laboratory study in this field. As far as can be determined, very little work has been done to ascertain the manner in which algae are able to accumulate iodine and retain it against enormous concentration gradients. In search of suitable experimental organisms for such studies and under the assumption that such organisms should both accumulate iodine and lend themselves to modified microbiological procedures, numerous species of marine algae were examined.

The samples studied were collected alive in the field and air dried in the laboratories of the collectors (see footnotes of Table 1). Upon receipt, these collections were cleaned and redried at room temperature. A weighed amount (usually 1 gm.) was incinerated to a black ash in a porcelain crucible over a Bunsen burner. The ash was pulverized and mixed with 5 milliliters of distilled water and the soluble portion separated by centrifugation. The supernatant was shaken up with 1 milliliter chloroform, 2 milliliters hydrogen peroxide, and 1 milliliter glacial acetic acid. After several minutes, the presence of iodine was manifested by a pink to purple color in the chloroform layer, the intensity of the color increasing with iodine concentration. When the nonchloroform layer retained a brownish tinge, more hydrogen peroxide and acetic acid were added until decolorization occurred, and the mixture was reshaken. The color of the chloroform layer was compared to color standards containing known concentrations of iodine in chloroform. This method is assumed to be a satisfactory means of estimating the iodide content of the algal ash when iodide is present in concentrations of over 30 parts per million.

Quantitative estimations for iodine obtained in this investigation are presented in Table 1 and are expressed in milligrams per gram of dry weight of alga and in parts per million. Unused portions of the collections

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[1] Based in part upon data included in a thesis submitted to Cornell University in partial fulfillment of the requirements for the degree of Master of Science. This investigation was performed under the supervision of Dr. Maxwell S. Doty and Dr. Walter C. Muenscher and supported in part by grants from Cornell University and Graduate Research Funds of Northwestern University. Manuscript received February 20, 1952.

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TABLE 1
IODINE CONTENT OF VARIOUS SPECIES OF ALGAE

SPECIES TESTED	COLLECTION*	SOURCE†	MG. I_2/ GM. ALGA	PARTS PER MILLION
Chlorophyta				
Anadyomene stellata (Wulf.) C. Ag.	B 49–2134	B	0.156	160
Avrainvillea longicaulis (Kuetz.) Murray & Boodle.	B	B	0.024	20
Bryopsis plumosa (Hudson) C. Ag.	G	M	0.195	200
Chaetomorpha linum (Mueller) Kuetz.	G	M	0	0
	B 49–2203	B	0.110	100
Codium intertextum Collins & Hervey	B 49–2139	B	0.300	300
Codium setchellii Gardner	H	O	0.078	80
Dictyosphaeria cavernosa (Førsk.) Boergesen	D 8118	H	0	0
	D 8584	H	0.039	40
Halimeda monile (Ellis & Solander) Lamour.	B 49–2103	B	0.02	20
Ulva expansa (Setch.) Setch. & Gard.	H 1054	O	0.059	60
Phaeophyta				
Agarum cribrosum (Mertens) Bory	G 249	M	0.078	80
Alaria marginata Post. & Rupr.	H	O	0.059	60
Ascophyllum nodosum (L.) Le Jolis	G	M	0.156	160
Asperococcus echinatus (Mertens) Grev.	G 258	M	0.056	60
Chorda filum (L.) Lamour.	G	M	0.227	230
Chordaria flagelliformis (Mueller) C. Ag.	G 283	M	0.313	310
Cladostephus verticillatus (Light.) C. Ag.	G 277	M	1.094	1090
Coilodesme bulligera Stroemfelt	H 1019	O	0.234	230
Coilodesme californica (Rupr.) Kjellm.	H 1074, 1075	O	0.25	250
Cystoseira osmundacea (Menzies) C. Ag.	H	O	0.117	120
Desmarestia aculeata (L.) Lamour.	G 287	M	2.5	2500
Desmarestia munda Setch. & Gard.	H 7689	O	0.469	470
Dictyopteris plagiogramma (Mont.) Vickers	B 49–2081	B	0.234	230
	D 8561	H	0.02	20
Dictyosiphon foeniculaceus (Hudson) Grev.	G	M	0.284	280
Dictyota dichotoma (Hudson) Lamour.	B 49–2206	B	0.013	10
Ectocarpus siliculosus (Dillwyn) Lyngbye	G	M	0.087	90
Elachistea fucicola (Velley) Aresch.	G	M	0.195	200
Fucus evanescens C. Ag.	G 278	M	0	0
	H 1088	O	0.078	80
Fucus evanescens f. *oregonensis* Gard.	H 1077	O	0.078	80
Fucus furcatus C. Ag.	H 1078	O	0.117	120
Fucus spiralis L.	G	M	0.120	120
Fucus vesiculosus L.	G	M	0.052	50
Haplogloia andersonii (Farlow) Levring	H 1064	O	1.25	1250
Hedophyllum sessile (C. Ag.) Setch.	H	O	1.25	1250
Laminaria agardhii Kjellm.	G 268	M		
Young thallus			3.125	3130
Blade			2.083	2080
Stipe			1.563	1560
Haptera and rhizoids			5.0	5000
Laminaria andersonii Eaton in Hervey	H	O		
Blades			0.938	940
Upper stipe			5.0	5000
Laminaria digitata (L.) Edm.	G 279	M	1.041	1040
Laminaria saccharina (L.) Lamour.	H 1065	O		
Lower blades			1.25	1250
Laminaria sinclairii (Aresch.) Anderson	H 1058	O		
Blades			5.0	5000
Haptera and rhizoids			1.875	1880
Stipe			3.75	3750
Lessoniopsis littoralis (Tilden) Reinke	H	O	0.117	120
Macrocystis integrifolia Bory	H	O		
Blades			0.938	940
Axis of branch			0.117	120

TABLE 1—continued

SPECIES TESTED	COLLECTION*	SOURCE†	MG. I_2/ GM. ALGA	PARTS PER MILLION
Mesogloia divaricata (C. Ag.) Kuetz	G	M	0.240	240
Nereocystis luetkeana (Mertens) Post. & Rupr	H	O		
Air bladder			0.938	940
Sterile blades			0.625	630
Pelvetiopsis limitata (Setch.) Gard	H	O	0.156	160
Postelsia palmaeformis Rupr	H	O		
Blades			1.25	1250
Stipe			0.469	470
Holdfast			1.25	1250
Pterygophora californica Rupr	H	O	0.029	30
Ralfsia clavata (Carm.) Crouan	G	M	0.087	90
Sargassum sp	D 8572	H	0.02	20
Sargassum filipendula C. Ag	G	M	0.156	160
Sargassum kjellmanianum Yendo	H 1067	O	0.02	20
Sargassum natans (L.) J. Meyen	B 49–2067	B	0.059	60
Sargassum obtusifolium J. Ag	D 8114	H	0.029	30
Scytosiphon bullosus Saunders	H 1238	O	0.020	20
Soranthera ulvoidea Post. & Rupr	H 1074	O	0.234	230
Sphacelaria cirrhosa (Roth) C. Ag	G	M	0.314	310
Turbinaria tricostata Barton	B 49–2231	B	0.029	30
Rhodophyta				
Ahnfeltia concinna J. Ag	H 1233	O	0.02	20
Ahnfeltia plicata (Hudson) Fries	H 1219	O	0.117	120
Amphiroa fragilissima (L.) Lamour	B	B		
Coarse type			0.029	30
Fine type			0.156	160
Antithamnion uncinatum Gard	H 1145	O	0.02	20
Asparagopsis hamifera (Hariot) Okamura	G 286	M	0.938	940
Asparagopsis sanfordiana Harvey	D 8663	H	1.25	1250
Laurencia spectabilis Post. & Rupr	H 1107	O	0.078	80
Lophocladia trichoclados (Mertens) Schmitz	B 50–426	B	0.117	120
	B 49–2086	B	0.117	120
Asparagopsis taxiformis (Delile) Collins & Hervey	B 50–516	B	1.875	1875
Bostrychia scorpioides var. *montagnei* (Harvey) Post.	B 50–382	B	0.01	10
Botryglossum farlowianum (J. Ag.) De Toni	H	O	0.313	310
Callithamnion baileyi Harvey	G 203	M	0.234	230
Callithamnion pikeanum Harvey	H	O	0.039	40
Centroceras clavulatum (C. Ag.) Mont	B 49–2151	B	0.234	230
Ceramium eatonianum (Farlow) De Toni	H	O	0.039	40
Corallina officinalis L	G	M	0.02	20
Cryptopleura brevis Gard	H 7680	O	0.029	30
Cryptosiphonia woodii J. Ag	H 7685	O	0.117	120
Cystoclonium purpureum (Hudson) Batters	G 204, 270	M	trace	
Cystoclonium purpureum var. *cirrhosum* Harvey	G	M	0.039	40
Galaxaura obtusata (Ellis & Solander) Lamour	B 49–2144	B	0.117	120
Galaxaura squalida Kjellm	B 49–2070	B	0.059	60
Gelidium arborescens Gard	H 1030	O	0.039	40
Gelidium corneum (Hudson) Lamour	D 8709	H	0.029	30
Gelidium coulteri Harvey	H 1031, 7687	O	0.117	120
Gelidium crinale (Turner) Lamour	G	M	0.117	120
Laurencia obtusa (Hudson) Lamour				
Green phase	B 49–2195	B	0.039	40
Yellow phase	B 49–2194	B	0.117	120
Microcladia borealis Rupr	H 1130	O	0.02	20
Odonthalia floccosa (Esper) Falken	H 1133	O	0.078	80
Odonthalia washingtoniensis Kylin	H 1114	O	0.407	420
Phycodrys rubens (Hudson) Batters	G 285	M	0.313	310
Phyllophora membranifolia (Good. & Woodw.) J. Ag.	G	M	trace	trace
Plocamium pacificum Kylin	H 1191	O	0.029	30

TABLE 1—continued

SPECIES TESTED	COLLECTION*	SOURCE†	MG. I_2/ GM. ALGA	PARTS PER MILLION
Plumaria filicina (Farlow) Kuntz	H 7681	O	1.25	1250
Plumaria hypnoides (Harvey) Kuntz	H 1236	O	0.078	80
Plumaria sericea (Harvey) Rupr.	G	M	0.32	320
Polyides rotundus (Gmelin) Grev.	G	M	0.039	40
Polyneura latissima (Harvey) Kylin	H 1147	O	0.039	40
Polysiphonia elongata (Hudson) Harvey	G	M	trace	trace
Polysiphonia lanosa (L.) Tandy	G	M	0.438	440
Porphyra naiadum Anderson	H 1023	O	0.313	310
Pterochondria woodii (Harvey) Hollenberg	H 1148	O	0.078	80
Pterosiphonia bipinnata var. *robusta* (Gard.) Doty	H 1213	O	0.078	80
Rhodomela larix (Turner) C. Ag.	H 1033	O	0.156	160
Rhodymenia californica Kylin	H 1196	O	0.078	80
Spermothamnion turneri (Mertens) Aresch.	G	M	0.313	310
Zanardinula andersonii (J. Ag.) Papenfuss	H 7674	O	0.039	40
Zanardinula filiformis (Kylin) Papenfuss	H 7671	O	0.078	80
Zanardinula lanceolata (Harvey) De Toni	H 7672	O	0.02	20
	H 7673	O	0.059	60
Zanardinula lyallii (Harvey) De Toni	H 7675	O	0.117	120
	H 1050	O	0	0

* Collector: B, A. J. Bernatowicz; D, M. S. Doty; G, M. R. Grimm; H, L. Horowitz.
† Location: B, Bermuda; H, Hawaii; M, Woods Hole, Massachusetts; O, Cape Arago, Oregon.

treated remain for the most part in the herbaria of the various collectors. The collector and collector's number, where given, are shown in Table 1.

As is shown in Table 1, very little iodine was detected in the Chlorophyta, a finding which is in agreement with the data of other investigators. Phaeophyta such as *Laminaria* and *Desmarestia* had the highest concentrations of iodine. However, these genera are large forms difficult to maintain in the laboratory. *Asparagopsis* and *Plumaria*, both Rhodophyta, store iodine in considerable amounts and have the advantage of convenient cultural size.

A variation of iodine content was found in different thalli collected from the same locality. For example, one sample of *Laminaria agardhii* collected from Woods Hole showed no iodine while other specimens of the same species from the same vicinity showed an accumulation of 5,000 parts per million. Turrentine (1912) records similar variations with *L. saccharina*.

In a consideration of the iodine content of the same thallus, marked differences were noted by Turrentine (1912), Cameron (1915), and Black (1948). Fritsch (1945) reported that the greatest accumulation of iodine was in the actively growing cells at the base of the blade. Table 1 shows that the blades of *L. sinclairii* contained 5,000, haptera and rhizoids 1,880, and stipe 3,750 parts per million. Iodine determinations of other species of *Laminaria* provided similar results. Thus, in *Laminaria*, there appears to be an analogy between the activity of growth-regulating substances observed by Williams (1949) and the distribution and amounts of iodine present.

Table 1 also indicates that two phases of *Laurencia obtusa* contained different amounts of iodine—the yellow phase three times as much iodine as the green phase. The same appears to be true of two growth forms of *Amphiroa fragilissima*. A fine form contained more than five times as much iodine as a coarse form. A potential taxonomic use of the iodide test is suggested here as a supplement to the vague morphological criteria currently used in separating the infrageneric taxa of such genera.

The data presented indicate that *Asparagopsis* and *Plumaria* would be the most suitable species for further investigation. Their adaptation in this study allows the conjecture that they may be readily adaptable to methods of culture, iodine uptake, plant metabolism, and tracer studies.

A listing of algae which gave negative tests for iodine is presented here. These species represent approximately 50 per cent of all organisms tested. The source of the samples is as indicated in Table 1.

LIST OF SPECIES YIELDING NEGATIVE IODINE CONTENT

Cyanophyta	
Calothrix confervicola (Roth) Ag. ex. Born. & Flah.	M
Lyngbya majuscula "(Dillwyn) Harvey ex. Gomot"	H
Chlorophyta	
Boodlea composita (Harvey) Brand	H
Caulerpa crassifolia (C. Ag.) J. Ag.	B
Caulerpa peltata (Turner) Lamour.	B
Caulerpa racemosa var. *laetevirens* (Mont.) Weber-van Bosse	B
Caulerpa sertularioides (Gmelin) Howe	B
Caulerpa verticillata J. Ag.	B
Caulerpa webbiana Mont.	H
Chaetomorpha antennina (Bory) Kuetz.	H
Cladophora sp.	H
Cladophoropsis membranacea (C. Ag.) Børg.	B
Codium decorticatum (Woodw.) Howe	B
Codium fragile (Suringar) Hariot	O
Cympolia barbata (L.) Lamour.	B
Enteromorpha clathrata (Roth) Grev.	O
Enteromorpha intestinalis (L.) Link	O
Enteromorpha linza var. *flexicaulis* Doty	O
Halimeda discoidea Decaisne	H
Monostroma grevillei (Thuret) Wittr.	O
Spongomorpha coalita (Rupr.) Collins	O
Udotea flabellum (Ellis & Solander) Howe	B
Ulva angusta Setch. & Gard.	O
Ulva fasciata Delile	H B
Ulva lactuca L.	M H
Ulva lobata (Kuetz.) Setch. & Gard.	O
Urospora penicilliformis (Roth) Aresch.	O
Vaucheria thuretii Woronin	O
Phaeophyta	
Aegira virescens (Carm.) Setch. & Gard.	M
Colpomenia sinuosa (Roth) Derbes & Solier	B
Costaria mertensii J. Ag.	O
Dictyopteris delicatula Lamour.	B
Dictyopteris justii Lamour.	B
Dictyota dentata Lamour.	B
Dictyota divaricata Lamour.	B
Dilophus guineensis (Kuetz.) J. Ag.	B
Ectocarpus indicus Sonder	H
Egregia menziesii (Turner) Aresch	O
Heterochordaria abietina (Rupr.) Setch. & Gard.	O
Hydroclathrus clathratus (Bory) Howe	B
Ilea fascia (Mueller) Fries	O M
Leathesia difformis (L.) Aresch.	M O
Padina commersonii Bory	H
Padina pavonia (L.) Gaillon	B
Padina sanctae-crucis Børg.	B
Pocockiella variegata (Lamour.) Papenfuss	B
Punctaria latifolia Grev.	M
Scytosiphon lomentaria (Lyngbye) J. Ag.	O M
Spatoglossum schroederi (Mertens) J. Ag.	B
Zonaria zonalis (Lamour.) Howe	B
Rhodophyta	
Acanthophora spicifera (Vahl) Børg.	B
Agardhiella tenera (J. Ag.) Schmitz	M
Bangia vermicularis Harvey	O
Callophyllis crenulata Setch.	O
Callophyllis megalocarpa Setch. & Gard.	O
Ceramium pacificum (Collins) Kylin	O
Ceramium rubrum (Hudson) C. Ag.	O
Ceramium tenuissimum (Lyngbye) J. Ag.	H
Champia parvula (C. Ag.) Harvey	M
Chrondrus crispus (L.) Stackh.	M
Chrondia sedifolia Harvey	M
Constantinea simplex Setch.	O
Cumagloia andersonii (Farlow) Setch. & Gard.	O
Delesseria decipiens J. Ag.	O
Dilsea californica (J. Ag.) Schmitz	O
Dumontia incrassata (Mueller) Lamour.	M

Endocladia muricata (Harvey) J. Ag.	O
Erythrophyllum delesserioides J. Ag.	O
Eucheuma isiforme (C. Ag.) J. Ag.	B
Farlowia mollis (Harvey & Bailey) Farlow & Setch.	O
Galaxaura cylindrica (Ellis & Solander) Lamour.	B
Galaxaura marginata (Ellis & Solander) Lamour.	B
Halymenia formosa Kutz.	H
Kylinia sp.	H
Laurencia palisada Yamada	H
Liagora farinosa Lamour.	B
Liagora maxima Butters	H
Liagora valida Harvey	B H
Lomentaria baileyana (Harvey) Farlow	M
Nemalion multifidum (Weber & Mohr) J. Ag.	M
Opuntiella californica (Farlow) Kylin	O
Petrocelis franciscana Setch. & Gard.	O
Phyllophora brodaei (Turner) J. Ag.	M
Polysiphonia collinsii Hollenberg	O
Polysiphonia fibrillosa Grev.	M
Polysiphonia harveyi Bailey	M
Polysiphonia paniculata Mont.	O
Polysiphonia variegata (C. Ag.) Zanardini	M
Porphyra nerocystis Anderson	O
Porphyra perforata J. Ag.	O
Porphyra umbilicalis (L.) J. Ag.	M
Porphyra variegata (Kjellm.) Hus	O
Pterosiphonia bipinnata (Post. & Rupr.) Falken.	O
Rhodymenia pacifica Kylin	O
Rhodymenia palmata (L.) Grev.	M
Schizymenia pacifica Kylin	O
Spyridia spinella Sander	H
Spyridia filamentosa (Wulf.) Harvey	M B
Thuretia borneti Vickers	B
Trichogloea subnuda Howe	H
Wurdemannia miniata (Drap.) Feldman & Hamel	B

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News Notes

Scientific reconnaissance of Taongi and Bikar, in the Marshall Islands, has been started by a two-man field party of the Geological Survey, Secretary of the Interior Oscar L. Chapman has announced.

The geology will be mapped and hydrologic data will be collected by Charles G. Johnson, geologist, stationed at Tokyo, Japan. Vegetation studies will be made by Dr. F. Raymond Fosberg, botanist, Washington, D. C.

Knowledge of these atolls is expected to be of special significance because no scientific observations other than those made at a distance (from shipboard) have been recorded. They are reported never to have been inhabited and therefore should be almost entirely primitive and show less change from their original state as a result of human alterations. Further, they lie in the northernmost and driest part of the Marshalls so the vegetation is expected to differ somewhat from that found on atolls having heavier rainfall.

Inspection of Taongi and Bikar was scheduled as a major objective of the Marshall Islands reconnaissance made by F. Stearns MacNeil, Dr. Fosberg, and Theodore Arnow of the Geological Survey, from November, 1951, to April, 1952. During that time the field party examined more than 60 islands on the atolls of Utirik, Taka, Ailuk, Likiep, Jemo, Kwajalein, Ujelang, Wotho, Ujae, and Lae, but unfortunately a landing could not be made on Taongi or Bikar because of rough seas and strong currents.

The islands visited thus far range in size from tiny sand bars to islands nearly 3 miles long. Although it was not possible to study every island in every atoll, an attempt was made to visit the ones that would show the conditions on every part of an atoll. It is believed that most, if not all, of the stages in both the construction and the ultimate destruction of atoll islands were observed. Special attention was given to the types of materials comprising atoll sediments and to the shape and location of the deposits themselves. Direct observation of currents and waves actually transporting sediments contributed materially to an understanding of the mechanics involved in the construction of various physical forms.

Hydrologic studies indicate that a lens of fresh or relatively fresh ground water exists in each of the large islands of the atoll. This fresh-water lens is maintained by the accumulation of rain water in the clastic and reef deposits forming the island, and because of its lesser specific gravity, floats on the sea water saturating the rocks below it. The thickness, areal extent, and relative freshness of the lens are governed by the size of the island, the amount and distribution of rainfall, and the nature of the rocks containing the lens. Short-term observations were made of ground-water levels, tidal fluctuations in the ground-water bodies, and the quality of the water. Wells dug by natives and test holes dug during the investigation were utilized for the observations and, where conditions permitted, continuous records of water-level fluctuations were obtained by means of an automatic recording gauge. Ground-water levels and the relations between water-level fluctuations and ocean tides were determined from datum planes and tide gauges established by the geodetic control party. Quality-of-water studies included determinations of total salinity, chloride, *p*H, and hardness on samples from more than 100 wells and test holes. These determinations were made also for samples of ocean water, lagoon water, and rain water. The data obtained during the observations will be of value in the estimation of quantity and quality of water available in islands of atolls for present and future utilization.

Examination of the soils showed that, in most situations, there has been rather little alteration of the original sediments, the foraminiferal sand, the coral, and the algal fragments which make up the surface layers of the islands. Varying amounts of humus have been added to the surface layers, producing a greater or lesser darkening in color. In places, a thin layer of a form of peat has accumulated, and in excavations formerly used for taro gardens a dark-brown muck may be found. In many parts, burning of coconut trash and subsequent grass fires greatly reduce the amount of humus added to the soil. An interesting phenomenon often noted is that of buried soils — layers in which a noticeable amount of humus has accumulated and which have then been buried to some depth by wind- or wave-transported sand or rubble. The frequency of these buried soils and of areas of completely fresh, unaltered coral sand and gravel, showing recent deposition or denudation, is an indication of the general instability of and domination by the sea, which are among the most outstanding features of the coral-atoll environment.

The vegetation growing on these soils is relatively simple, though a fair number of distinct types in various stages of development are evident. By far the greatest part of the area visited has been cleared and planted to coconuts, obliterating all evidence of the original vegetation. However, enough undisturbed spots were found so that one of the most significant contributions of the expedition may be toward the revealing of original conditions that prevailed on coral atolls, before the advent of man and the coconut. It is probable that on the older parts of the islands forests of great trees, up to 100 feet tall, were the dominant vegetation. On newer areas and those exposed to strong winds, the vegetation is scrubby, dense, tangled, and difficult to penetrate.

In general, the soils on the atolls visited did not appear to be infertile, but nevertheless only a few kinds of plants can be raised in gardens. The reason for failure of most kinds is not apparent, but it may be an excess of salt. The amount of ocean spray that blows in, especially on the windward sides of the islands, is undoubtedly a controlling factor in the development of both natural and imported vegetation. The salinity of the ground water also must exert an important influence where it lies at shallow depth.

The current research program is being carried out under the Pacific Geologic Mapping Program by cooperative agreement between the Geological Survey and the Corps of Engineers, United States Army. Johnson and Fosberg recently joined a new survey party of the 71st Engineer Survey Liaison Detachment at Wake Island. Their work on Taongi and Bikar will require about 3 weeks and will be done while United States Army Engineer personnel establish ground control for the preparation of topographic maps.

The Tenth General Assembly of the Union Radio-Scientifique Internationale was held in Sydney from August 11 to 21, 1952, under the presidency of Sir Edward Appleton, F.R.S. This was the first occasion on which an International Scientific Union has met in Australia or, in fact, in any country outside Europe and the United States. That the Union honored Australia by holding its Assembly there is tangible recognition of the outstanding contribution which Australian research workers have made in the field of radio science.

The meetings of the Australian and New Zealand Association for the Advancement of Science were held in Sydney from August 20 to 27. The Centenary of the University of Sydney was celebrated by appropriate ceremonies at this time.

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